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VOLUME 7 NUMBER 3

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NOVEMBER, 1923

PUBLISHED BIMONTHLY BY AMERICAN MEDICAL ASSOCIATION, 535 NORTH DEARBORN STREET, CHICAGO, ILLINOIS. ANNUAL SUBSCRIPTION, $8.00

Entered as Second-Class Matter, July 14, 1920, at the Postoffice at Chicago, Illinois, Under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized July 29, 1920.

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Correspondence.

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ARCHIVES OF SURGERY

VOL. 7 NOVEMBER, 1923 No. 3

A CLINICAL AND PATHOLOGIC STUDY OF TEN BONE TUMORS *

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In spite of the many excellent publications on tumors of bone in the recent literature, the average surgeon is puzzled as to the diagnosis and treatment. A review of some of the cases which we have observed convinces us that there is good reason for bewilderment.

We gather from the writings of different men that there are three general approaches to a diagnosis of the type of any bone tumor. The clinical course, with the known age incidence of the various kinds of neoplasm, the location in the bone and the slowness or rapidity of growth give us the first lead toward the solution. The second factor which is of material assistance is a correctly interpreted roentgenogram, the large proportion of tumors giving characteristic appearances. Lastly, the diagnosis may be clinched by a microscopic study, either by means of a frozen section at the time of operation or by more thorough pathologic study after the tumor has been removed.

We have applied these three methods of study to our small group of cases.

REPORT OF CASES

CASE 1.—*History.*—C. S., a teamster, aged 47, admitted to New Haven Dispensary, Sept. 7, 1920, with a complaint of "sore hand," in 1903 fell and broke his left wrist. In 1908, he again fell and broke the wrist in the same place. In 1910 and in 1911, the arm was broken at the wrist in falls from a house and from a wagon.

In 1913, he came to the New Haven Dispensary, complaining of a sore hand. Examination revealed a fracture of the lower third of the left radius. Roentgenograms taken Feb. 25, 1913, showed a many chambered cavity of the lower end of the radius. The cortex was preserved and the roentgenologist considered the picture typical of giant cell tumor (Fig. 1). Splints were applied The patient next appeared, Sept. 7, 1920, with a tremendous swelling involving the lower third of the left forearm to the wrist. This growth had been slowly enlarging for seven years.

Physical Examination.—The patient's condition was normal throughout except for the large, nodular, irregular swelling which surrounded the left wrist, measuring from 6 to 7 inches (15 to 17.5 cm.) in diameter. It was soft in places and had many tender areas, but the general consistency was firm and solid. On palpation, it did not feel like bone, and there was no egg-shell

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crackling elicited. The mass was firmly adherent to the bony structures. The skin over it showed evidences of tension by its shiny, red appearance and orange peel character, and by the purple distended veins (Fig. 2).

The roentgen-ray revealed a destructive process of the whole lower third of the radius. There was also an irregular overgrowth of bone in the same region and invasion of the surrounding soft parts. The roentgen-ray appearance was now typical of an osteogenic sarcoma of the radius (Fig. 3).

Fig. 1 (Case 1).—Many chambered cystic growth at the lower end of the radius. The appearance suggests giant cell tumor.

Operation.—The patient was sent to the New Haven Hospital for roentgen-ray therapy. In September, 1920, an amputation was performed by Dr. T. S. McDermott at Springside Hospital.

Pathologic Examination (Fig. 4).—The specimen consisted of a forearm and hand, the normal contour of which was greatly distorted by a huge tumor surrounding the wrist like a cuff. The tumor tissue, it was estimated, weighed

between 1 and 2 pounds (453.6 and 907 gm.). The diameter of the neoplasm was approximately 12 cm. The tumor had not only destroyed the lower end of the radius, it had also involved the carpus and more extensively the surrounding soft parts. On section, the tumor appeared to have developed largely as a circumscribed encapsulated growth. Although some of the extensor tendons passed through the main mass of its structure, one was led to believe by the circumscribed appearance of the most peripheral portions of the growth that this involvement of the tendons took place by a process of envelopment and, later, fusion of the surrounding tumor processes. The circumscribed appearance referred to appeared to be really due to encapsulation. This was best seen on the side of the tumor farthest up the forearm, where a nodular process of the main mass was extending upward along the lateral surface of the radius, push-

Fig. 2 (Case 1).—Appearance of tumor when patient entered the dispensary.

ing away the tendon and belly of the flexor carpi radialis without infiltration of either. The same encapsulation prevailed in those parts of the periphery of the tumor nearest the skin. The latter everywhere was separated from tumor tissue, although where the skin was under greatest pressure, it seemed adherent to the thin capsule.

At its lower end, the tumor had obliterated the wrist joint, and extensions of it had pushed between the carpal bones. As a result, the appearance was more suggestive of infiltration, in the sense of invading neighboring structures by diffuse growth through the tumor capsule. Here, in places, the cartilage covering of individual carpal bones was destroyed by pressure atrophy or invasion (?), but the carpal bones themselves did not show definite invasion (macroscopically).

The specimen was not examined until after fixation in formaldehyd, but it was much firmer than the typical giant cell tumor, and for the most part was of a quite dense consistency, suggestive of that of fibrous tissue. This density was especially marked where the lower end of the radius was replaced by tumor. Here, and near the ulna, the consistency was that of diffuse new bone formation. There was, however, a soft area 3 or 4 cm. in diameter on the radial side of the mass opposite the wrist joint, which was light brown and of crumbly consistency. In the gross, this was thought probably to be

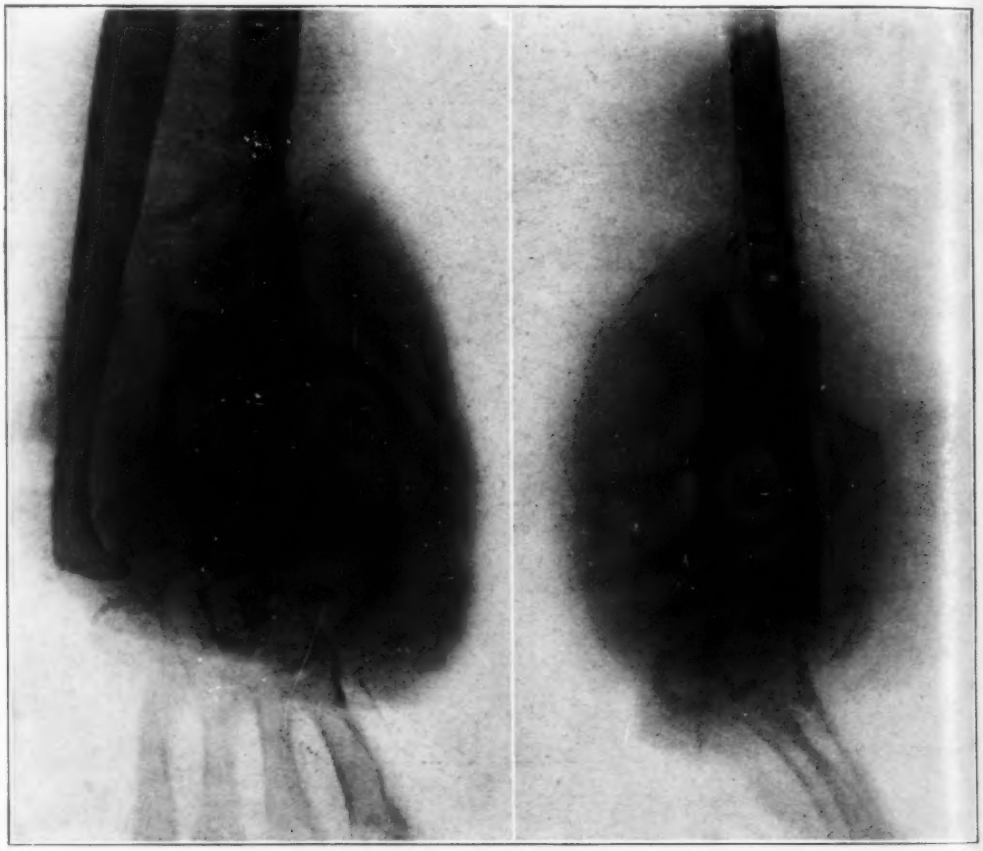

Fig. 3 (Case 1).—Roentgen-ray appearance of growth shown in Figure 2. There is bone destruction and new bone formation, suggestive of osteogenic sarcoma.

a place which would show either giant cell areas or malignancy on histologic examination. (In both of these assumptions, we were wrong).

For the most part, the tumor tissue was rather pink, and the cut surface suggested a growth in the form of fibrous whorls and nodules.

Numerous blocks were selected for microscopic study.

Microscopic examination: Sections were cut from several different portions of the tumor. All showed essentially the same picture, that of a very fibrous

tumor with extensive hyalinized areas (Fig. 5). No giant cells were found in any of the sections, although diligently searched for. Sections from the single area of soft tissue noted in the gross showed a diffuse necrosis of cells, the preexisting nature of which it was impossible to determine definitely. They appeared as vague shadows often polyhedral in outline. The periphery of this area of necrosis was surrounded by a zone of round-cell infiltration, most of

Fig. 4 (Case 1).—Gross specimen. The lower end of the radius is replaced by tumor tissue.

the cells being apparently of the lymphoid type, with occasional polymorphonuclears. There was no suggestion of tuberculosis.

Sections of the bone-containing tissue in the tumor showed definite new bone formation (osteoid tissue), with deeply staining bone cells forming delicate interlacing patterns (Fig. 6). This is an unusual picture in central bone tumors.

The histology is similar to that of the periosteal ossifying sarcoma studied by Le Count [1] and of the central "sclerosing osteogenic sarcoma" of Ewing.[2]

The final diagnosis was: medullary sclerosing osteogenic sarcoma of the lower third of radius.

April 20, 1923: The patient was seen today. The amputation stump was well healed and showed no signs of trouble. Careful examination of the

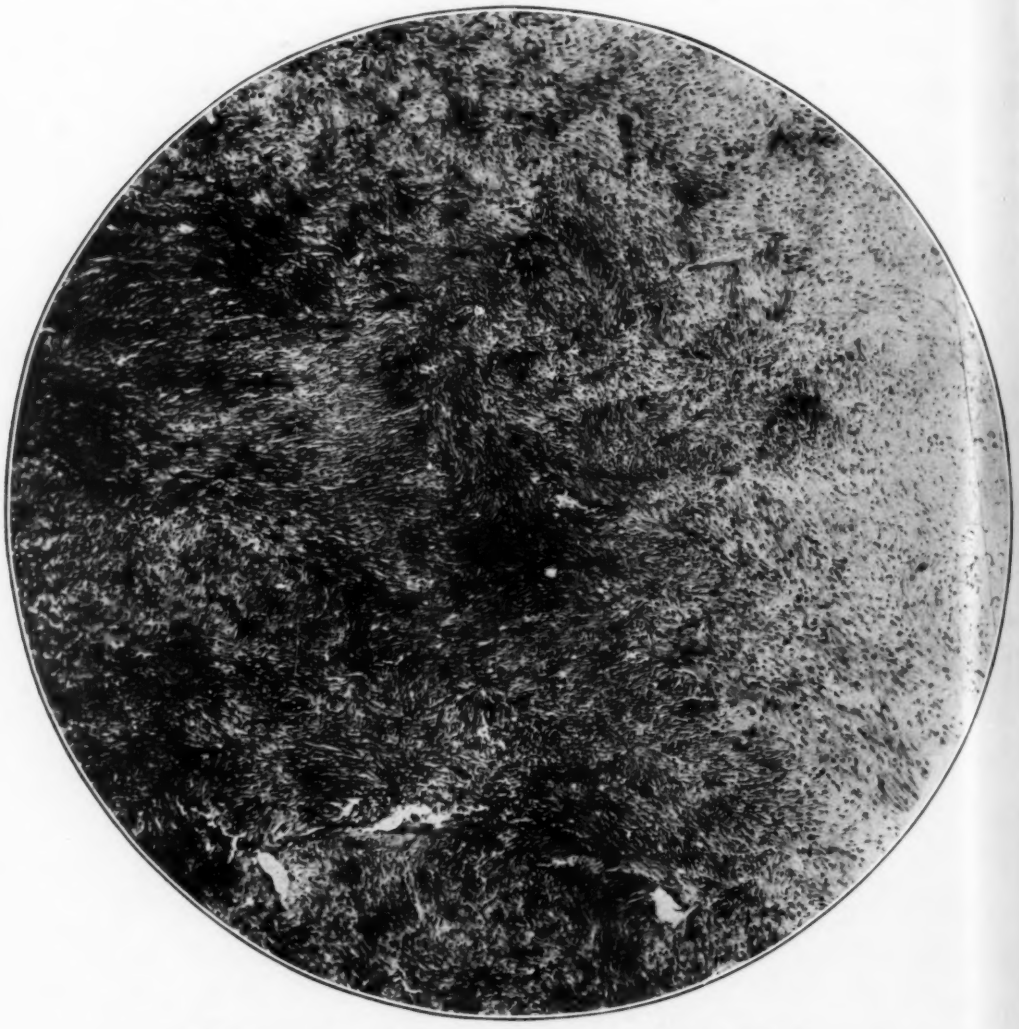

Fig. 5 (Case 1).—Arrangement of fibrous tissue in whorls.

axillary lymph glands and chest did not reveal any evidence of metastasis. The patient is working daily and feels normal in every way.

1. Le Count, E. R.: Bull. Johns Hopkins Hosp. **20**:361-370, 1909.

2. Ewing, James: Neoplastic Diseases, Philadelphia, W. B. Saunders Company, 1919, p. 270.

From a clinical point of view, the tumor in this case should be a benign growth. The history of repeated fracture, with the slow painless enlargement of the left wrist over seven years before the patient sought relief, favors a process which certainly could not be

Fig. 6 (Case 1).—The interlacing bony strands, presenting the appearance of a black network.

of a very malignant character. The course since amputation is also in accord with such a view. The first roentgenogram would be interpreted by a majority of roentgenologists as a giant cell tumor of the lower end of the radius. This is a favorite site for such tumors. The

bone is not eroded and there is no formation of new bone. The many chambered cavity with expansion of the cortex, replacement of the normal contour and architecture, and extension to the very end of the epiphysis are typical of giant cell tumor. The roentgenogram taken seven years later would certainly not bear such an interpretation. Here, we have actual destruction of bone, and irregular new bone deposit. Although Bloodgood has shown that giant cell tumors may break through the cortex, his roentgen-ray pictures do not give the new bone

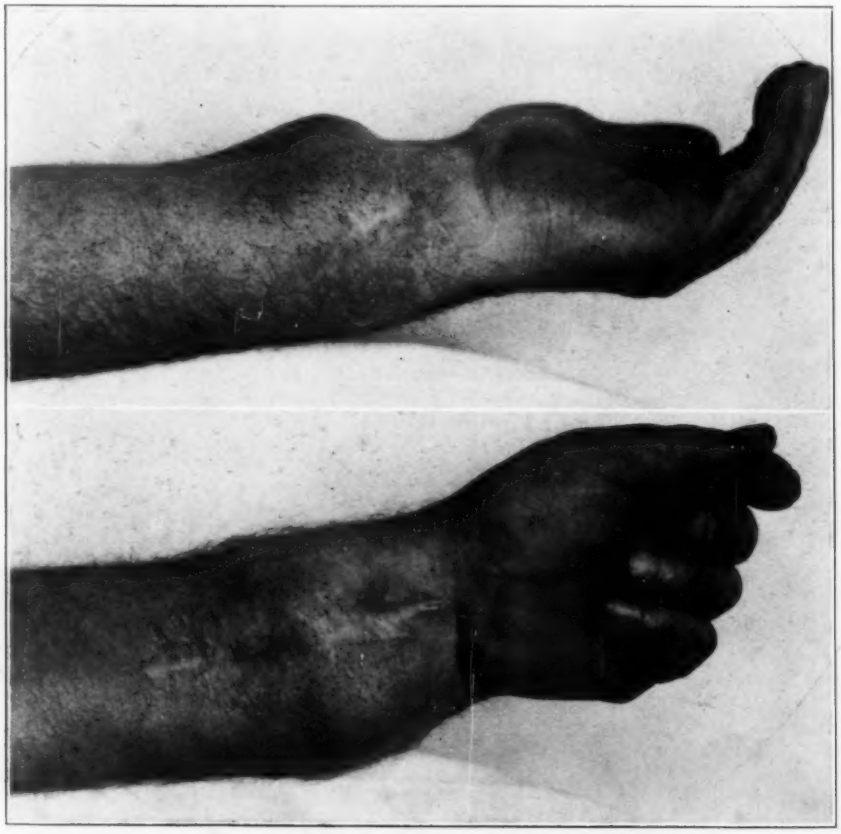

Fig. 7 (Case 2).—Appearance of tumor when patient was admitted to hospital, in March, 1922.

formation and patchy destruction as in this case. Most interpretations of this roentgenogram without the clinical history would be osteogenic sarcoma.

From the gross pathology of this tumor, it is rather difficult to say positively that the growth did not start as a periosteal tumor, although one inclines definitely to the opinion that the neoplasm was of central

origin. The mesial cortex of the radius for a distance of 6 cm. was entirely replaced by tumor continuous with that filling the shaft. Similarly, there was no trace left of the epiphyseal line, and only traces remained of the epiphysis itself. The lateral surface of the radius could be traced slightly better, but apparently had been perforated at several points and destroyed entirely at the lower end. The new growth of bone was not of the extensive degree and radiating form usually found in the bone-producing tumors of periosteal origin.

The question as to whether it is periosteal or of central origin is of considerable interest because of the greater rarity of bone-producing

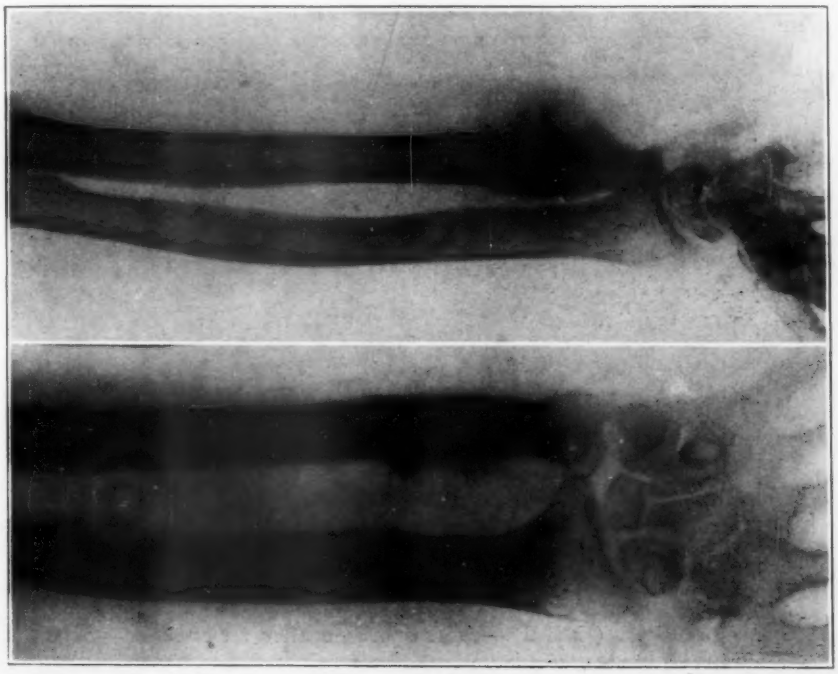

Fig. 8 (Case 2).—Roentgen-ray appearance of growth shown in Figure 7. The new bone formation about the lower end of the ulna suggests periosteal sarcoma.

tumors of central origin, and, more important, on account of the relatively slower growth of the central "sclerosing" tumor, with consequent influence on prognosis.

Le Count, in 1909, made an excellent study of ossifying bone tumors, in which the literature was carefully reviewed. The histology of bone production was studied as manifested in his patient with periosteal osteosarcoma, who died with pulmonary osseous metastases. With regard to the rarity of the central type of tumor (the myelogenous

ossifying tumor), he states that Benecke, in 1904, when reporting such a case, was able to find but one other such case in the literature (that reported by Virchow). Ewing (1922) describes the central type of ossifying tumor and reintroduces the term "sclerosing" to include this neoplasm in his classification. Originally, Virchow and Volkmann used the term "sclerosing osteoid sarcoma." This "sclerosing" central tumor is apparently a very distinct clinical-pathologic entity. Histologically, it is characterized by the production of hyaline osteoid tissue, the so-called "bone-cartilage" of Billroth (cited by Le Count), which is at first loosely spaced or composed of delicate interlacing strands (Fig. 6), but which later may become hard, compact bone. Clinically, the disease

Fig. 9 (Case 2).—Gross specimen after removal.

runs a course of from five to twenty-five years (Ewing), metastases probably occurring early, yet taking years to develop sufficiently for thoracic signs to be detected.

Dr. Morton has raised the interesting question as to whether such a tumor as that reported above might be a result of a reparative process in a giant cell tumor that had broken through the bone capsule. There is no basis for such a hypothesis, except possibly the analogous process that occurs in bone cysts some of which have giant cell tissue in the cyst lining. There is scarcely sufficient data, however, for intelligent discussion of this possibility. It seems likely that if the present tumor is the result of efforts at healing of a giant cell tumor the repeated trauma extending over a period of several years has had the effect

of stimulating this reparative tissue to such an extent that the process has become one with the power of independent growth beyond the original desideratum.

In summary, we have here a tumor with a clinically benign course, with one roentgenogram typical of giant cell tumor, and another typical of osteogenic sarcoma, and a pathologic picture which shows no giant cells, but a dense fibrous tissue and lacy bone structure which is probably malignant.

We feel confident that amputation was, in this case, the ideal treatment. It removed a growth of probable malignant nature, possibly before metastasis had occurred, and the after course has been satisfactory. Local excision and grafting would have been a slow and by no means sure procedure, possibly accompanied by infection and almost surely resulting in poor function of the wrist.

CASE 2.—*History.*—J. W., a cigar maker, aged 51, admitted to New Haven Hospital, March 6, 1922, with the complaint of tumor of the left wrist, had always been a strong and healthy person. There was a Colles fracture of the left wrist at 14 years, and "rheumatism" in the left arm about the wrist since 1914. Otherwise there was nothing of note in the personal history. A small tumor appeared on the dorsum of the left wrist just above the joint in February, 1916. It was excised shortly after it was noted. In two or three months, the wrist became painful, and the growth recurred in the position as previously. In August, 1917, a surgeon removed the tumor and diagnosed the condition as "spindle-cell chondroma," presumably from a microscopic section, although this has not been verified.

The next trouble developed about one year later (Sept. 1, 1918), with the reappearance of swelling near the left wrist.

Examination.—The patient was admitted to the New Haven Hospital, four months later, when Dr. John Churchman made the following note (January, 1919): "The tumor is now a growth between the radius and ulna about 1 inch above the styloid process, involving both bones, across the arm to the dorsum of the wrist in the shape of a band. On the palmar surface, the bony growth is not prominent. There is some irregularity of the tendon sheath, which may be the result of operation. There are three scars on the palmar surface of the arm."

Operation (Jan. 7, 1919).—Dr. Churchman performed a resection of the tumor of the radius. The tumor mass involved the ulnar side of the lower end of the radius. No attachment to the ulna or to the extensor tendons was made out. The involved area was chiselled away, leaving a small arch of bone as the remainder of the lower end of the radius. The joint cavity of the wrist was opened on the posterior surface.

Course.—Recovery was uneventful, and the patient was discharged.

January 15: The pathologic report gave a diagnosis of chondroma (Fig. 10).

Shortly after the patient left the hospital, the growth recurred, slowly increasing in size. He went to New York, where he was admitted to the St. Luke's Hospital, July 19, 1920. The tumor at this time seemed to be situated between the two bones of the forearm, bulging out the volar surface of the wrist. It was hard, slightly tender, movable and about the size of a walnut. It was

excised, and the following pathologic report was made: "Section of the tumor shows it to be composed entirely of cartilage cells, many of them showing marked irregularities in form and distribution throughout the matrix. The growth has a very delicate fibrous sheath which carries a few blood vessels and extends into the tumor substance a short distance. The lacunae are very

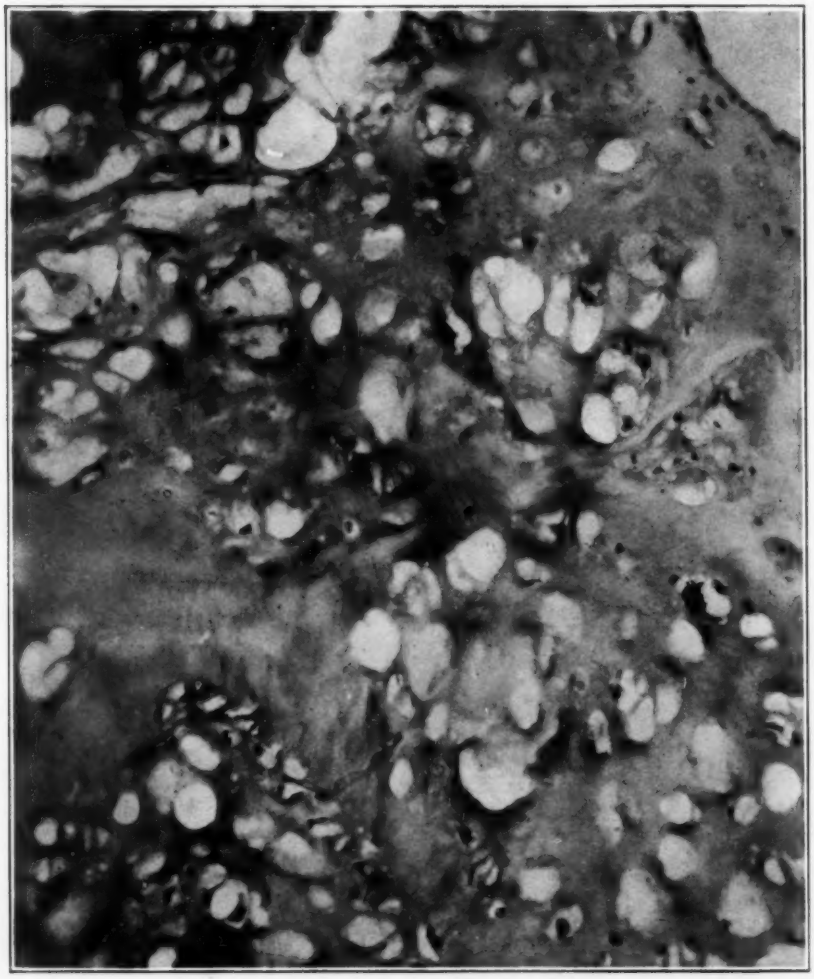

Fig. 10 (Case 2).—Microscopic section; chondroma (Jan. 15, 1919).

irregular, being without any of the normal paired arrangement. There is no fibrous stroma which is at all cellular and there appears to be no tendency toward calcification or ossification within the growth."

Recurrence promptly took place again, almost as soon as the scar of the operation had healed. The swelling occupied the volar surface of the left wrist. It slowly increased in size at first, and later assumed a more rapid growth. There had been pain radiating into the hand and fingers.

The patient entered the New Haven Hospital, March 6, 1922. Examination showed him to be obese and well developed. The findings were relatively negative. The lungs gave no evidence of a pathologic condition. There was an enlarged, easily palpable gland in the left axilla. On the volar surface of the left wrist, there were two tumors. One on the radial side distended the soft tissues over it markedly and measured roughly 3 by 3 by 4 cm. It was about the size of an English walnut, slightly tender, hard and movable. There was no inflammation of the overlying skin. The growth merged into a similar tumor on the ulnar side of the wrist, which was about four times as large, of similar consistency and firmly attached to the ulna itself. Between these two swellings, there was a linear scar of a previous operation, and there were two other scars, a large one over the middle portion of the dorsum of the arm, which extended from the wrist upward for 12 cm., and a smaller on the volar radial side. The condition at this time is shown by Figure 7.

Supination of the wrist was less than one half normal. Otherwise, the motions were not limited.

Roentgen-Ray Examination.—There was considerable swelling of the distal end of the right forearm, with some rather unusual pathologic condition of the radius and ulna. Beginning just below the head of the ulna, there was a fairly definite increase in density of the entire bone, obliterating the medullary cavity to some extent. The inner surface of the ulna was thickened, but had a smooth contour which extended partly around the bone, and was most marked on its anterior surface. There was definite bone formation with bone laid down perpendicular to the shaft. The radius showed a very slight irregularity, approximately 3 cm. from the lower end of the inner surface. The bone itself was apparently not greatly involved, but its dorsal and inner side near the end showed some deformity due to pressure. It was impossible to make a diagnosis from the roentgenogram alone. The lesion resembled a periosteal sarcoma. Owing to the fact that it was of such long duration and that there were two postoperative recurrences, it would seem that the tumor was more or less benign. It was, however, probably a mixed tumor which to some extent was malignant (Fig. 8). There was considerable fibrosis throughout both lungs.

Laboratory Findings.—The Wassermann reaction was not reported. The red blood count was 4,200,000; white blood count, 8,100; polymorphonuclears were 72 per cent.; large mononuclears, 16; small mononuclears, 12. Urinalysis revealed an occasional hyaline cast, and a few erythrocytes and leukocytes. Bence-Jones bodies not reported.

Second Operation.—March 7: A gland was removed from the left axilla under local anesthesia. The pathologic report was hyperplasia of the lymph gland.

March 10: Dr. Morton excised the lower half of the left ulna with the tumor. A bone graft was made to replace the removed bone. The tumor attached to the tendon sheath of the wrist flexors was removed.

Convalescence was uneventful and the patient was discharged on March 28, 1922.

Pathologic Examination (Fig. 9).—Grossly, the specimen consisted of a tumor partly surrounding the distal end of the ulna. The tumor was nodular and the greater part of it projected from one side of the bone. It was firm and cartilaginous, pearly white, with areas which had a slightly bluish tinge. The portion of ulna excised measured about 8 cm. in length including about 1 cm. beyond the upper end of the tumor. A longitudinal section through the center of the ulna showed that the tumor was closely attached to the bone,

from which small irregular shaped spicules were seen extending into the growth. There was no actual invasion of the bone. The tumor extended around, about three-quarters of the circumference of the bone. On cross section, the tumor measured about 2 cm. anteroposteriorly. Transversely, it measured about 6 cm. With the specimen, there was a small oval nodule measuring about 3 cm. in its greatest diameter. It was dark blue and slightly softer than the main tumor. A section through the mass showed that the center was cystic. The cut surface of this as well as of the main tumor was translucent and pale bluish gray. There were several small bits of tissue from which blocks were cut for histologic examination. Several blocks were also cut from other portions of the tumor.

Microscopic examination: The numerous sections studied showed marked differences from those made on previous admission to the hospital. At that time, there was a close resemblance between the tumor cells and normal cartilage, and there was much less evidence of activity. The different sections of the tumor showed essentially the same picture. The tissue resembled cartilage, although it varied quite markedly from the normal cartilage in structure. The variation was most conspicious in the number and arrangement of the cells and in their different staining characteristics. In most areas the cells were quite numerous and were irregularly arranged. They were largely polymorphous. Many showed two nuclei within a single cell. The nuclei were large, and were round or oval. The cytoplasm was pale pink and was homogeneous in appearance, varying quite markedly in size and shape. Occasionally, definite mitotic figures were seen. The matrix varied somewhat. In different areas, it appeared as a pale homogeneous, formless pink-staining material. The relative amount of cells and matrix varied considerably in different portions of the tumor. There were dense fibrous bands running through the tumor and dividing it into lobules of various sizes. These connective tissue septums extended inward from the capsule, which was moderately thickened and consisted of relatively dense and partly hyalinized fibrous tissue, with areas in which blood vessels were quite numerous.

There were a number of small areas that were definitely myxomatous in character, composed of typical myxoma cells, often stellate or triangular in shape, and situated in the substance of the tumor. The matrix here was very thin and delicate in appearance. There were also numerous areas showing a pale pink-staining matrix with very few cells (Fig. 11). The sections from the bits of tissue removed from the intermuscular septum showed no definite invasion by the tumor.

The diagnosis was myxochondroma, recurrent.

The patient remained well till August 7, when he noticed a small lump on the outer side of the forearm. On examination, a hard nodule about the size of a pea was palpable in the tissues near the ulnar side of the joint. A 2-inch (5 cm.) incision was made under procain anesthesia, and a small tumor exposed, apparently attached to the tendon sheath of the flexor carpi ulnaris. The tumor was removed with a portion of the tendon sheath and underlying muscle.

Pathologic examination revealed chondromatous tissue.

Nothing further was heard from the patient till March 13, 1923, although he had been repeatedly advised about reporting early and seemed to understand the reasons. Sometime in December, 1922, he observed a small swelling on the ulnar side of the wrist. It gradually increased in size and forced him to give up his work by interfering with the function of the arm. It was not painful.

On examination, there was a swelling easily seen about 2 inches (5 cm.) above the wrist on the ulnar side of the arm. It was very hard, smooth and encapsulated, and was not attached to the overlying skin. It was movable from side to side but not up and down. It did not move with the muscles and tendons of the wrist and hand. It was not tender, showed no signs of inflammation and felt about the size of a large plum. There was disturbance in the

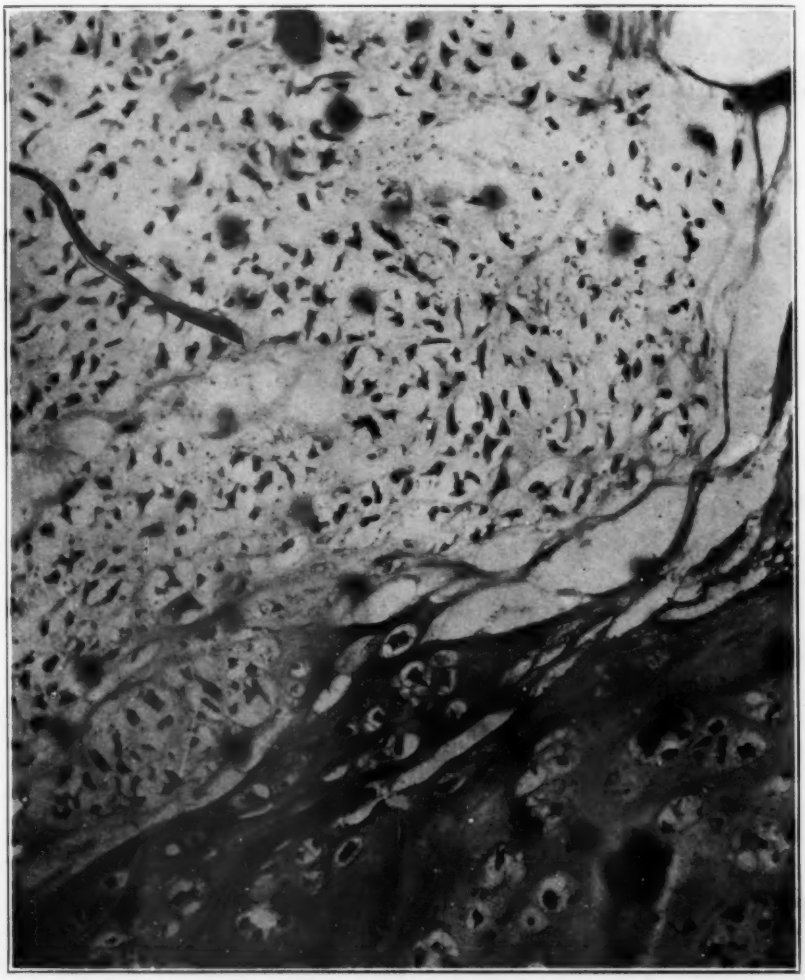

Fig. 11 (Case 2).—Microscopic section; myxochondroma (March 10, 1922).

sensory distribution of the median nerve and atrophy of the opponens and abductor muscles of the thumb. The Wassermann and Bence-Jones reactions were negative.

Third Operation (March 15, 1923).—The myxochondroma was removed. It was attached to the periosteum of the bone graft. The operative area was cauterized with actual cautery.

Summary.—A man of 51, always healthy, with a history of Colles fracture of the left wrist and rheumatism, had had a growth about the left wrist, either on the ulna or radius since 1916. It had been removed surgically, usually very thoroughly, with portions of the bone, seven times, with recurrence within six months as a rule. The growth consisted of cartilage, and in one specimen an area of myxomatous tissue was found.

May 15: There was no evidence of recurrence on very complete examination.

Bloodgood [3] called attention to the recurrence of apparently benign tumors after piece-meal removal and after enucleation. Such tumors as lipomas, intracanalicular myxomas, mixed tumors of the parotid and especially myxomas and myxochondromas of bone were included in the list. Numerous reports of recurring chondromas of bone may be found in the literature (De Witt Stetten,[4] Dittrich [5]). It is likewise known from animal experimentation that embryonal cartilage cells survive and grow better than any other transplanted normal tissues. Case 2 is, then, not unique in this regard. The clinical course in a middle-aged man covering a period of seven years is not that of a malignant growth. The repeated recurrences indicate that either complete removal has never been accomplished or that the tumor is potentially a very actively growing type. Pathologic studies do not bear out the latter hypothesis. The roentgen-ray examination of this tumor revealed irregular outgrowths of bone from the periosteum in a direction perpendicular to the shaft, with isolated deposits of bone in the soft parts; and the suspicion of periosteal sarcoma would be entertained by most roentgenologists, if no knowledge of the clinical history were at hand. The periosteal bony strands are, however, a little coarser than those seen in the general run of sarcomas.

With respect to the matter of frequent recurrence of chondromas after local removal, particularly after the so-called shelling out of these tumors, which has been emphasized by Bloodgood, it is of interest to seek for an explanation. A rational explanation would seem to be based in part on the fact, referred to above, of the ready transplantability of cartilage cells. In studying the sections of the tumor under discussion, it has occurred to us that an important additional factor is furnished by the peculiar structure of the peripheral portions of these tumors. On examination of the slides, one is struck by the fact that the cartilage cells and matrix extend to the edge of the chondroma nodule and that there is an entire absence of a true capsule in the sense of a fibrous or connective tissue periphery adherent to the tumor proper.

Chondromas may be covered with periosteum or merely with a capsular structure analogous to the perichondrium of normal cartilage.

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3. Bloodgood, J. C.: Ann. Surg. **72**:712-725 (Dec.) 1920.
4. Stetten, D.: Ann. Surg. **71**:200, 1920.
5. Dittrich: Deutsch. Ztschr. f. Chir. **172**:178-192, 1922.

Even in the chondroma, this covering may be composed of dense fibrous tissue. It is striking in the sections of this case that no such fibrous layer exists and that the tumor cells may in places be seen to extend to the edge of the growth. Where this is not the case, the periphery consists of either young (embryonal) cartilage cells or else clear hyaline cartilage matrix.

That the importance of the peripheral structure of chondroma has been realized before is indicated by Ewing's [2] statement (page 184): "To account for the invasive properties, one must assume that the active growth and infiltrative properties reside in the undifferentiated cells of the periphery of the cartilaginous nodules."

These facts seem to emphasize the importance of more careful study of the so-called "encapsulation" of benign tumors. Often it has seemed to us in these and other tumors that there is no real "encapsulation" in the sense of a fibrous covering and that many times the word circumscribed might be better applied. It is generally admitted that often the capsule is adventitious, representing the varying degree of reaction of adjacent tissues or even the approximation of such tissues (as periosteum) without "reaction" in the sense of a multiplication of connective-tissue cell layers.

The presence of myxomatous tissue in the tumor tissue removed at one of the operations in this case is a point of interest. A greater tendency to recurrence as well as to metastasis has been attributed to this histologic complication by Bloodgood.[3] It has also been thought that when once myxomatous tissue appears in a chondroma of bone, it is very apt to appear regularly in the recurrences. It should be noted that this latter possibility has not prevailed in the three recurrences in turn in which the growth was removed by Dr. Morton following the removal of the growth which contained myxomatous tissue.

The question of the proper treatment in this case is one that cannot be decided easily. Bloodgood [3] would have us amputate when myxomatous tissue is found and recurrence takes place, unless his views have been modified by further experience. Many reports of repeated local operations with final cure lend support to the more conservative approach to the problem. Chemical or thermal cauterization of the operative field should undoubtedly follow excision in every instance.

CASE 3.—*History.*—L. M., a baker, aged 30, admitted to New Haven Hospital, Nov. 10, 1920, with the complaint of a "broken leg," two months previously (September, 1920), fell from a bicycle and broke the left femur about 6 inches (15 cm.) above the knee. He was in a hospital for a month and then was discharged but remained in bed at home. Two days before admission, while getting out of bed with the aid of a crutch, he lost his balance and fell, breaking the femur again. A physician was called, and a posterior plaster-splint was applied before the patient was sent to the hospital.

Physical Examination.—The patient, a well-developed man, lay quietly in bed. The general physical examination was negative. The left thigh was encased in a plaster cast open in front and extending as high as the crest of the ilium. There was no evidence of swelling about the knee. There was an old fracture at the middle of the femur, with a small amount of motion at this point. There was 1¼ inches (3.2 cm.) of shortening of the left leg. The vital signs were normal. The urine showed a slight trace of albumin; also calcium oxalate crystals, but was otherwise negative.

Roentgen Ray Examination.—There was an old fracture of the left femur 20 cm. from the lower end. The lateral view revealed overriding of about 2.5 cm. There was marked callus formation, particularly on the outer side.

Blood taken for the Wassermann test was reported four plus for both alcoholic and cholesterinized antigens.

Treatment.—The patient was given a course of neo-arsphenamin, starting with 0.3 gm. and increasing to 0.6 gm. Treatments were given twice a week, six doses in all, with no apparent reaction.

November 24: A plaster spica was applied.

December 3: A roentgen-ray examination revealed fairly marked callus.

December 11: The patient had complained of pain in the left knee for the last two or three days. A small window was cut in the cast.

December 14: Roentgen-ray examination revealed that the position was approximately the same as on December 3. Callus formation was well marked.

December 23: A course of mercury and iodids was started.

Jan. 13, 1921: The cast was removed, January 12. Slight effusion in the knee was noted. The leg was fixed on a posterior splint. Roentgen-ray examination was requested and the condition was reported to be the same as on last examination.

January 25: The patient had been up in a wheel chair for several days.

January 27: The splint was removed. There was good bony union. The swelling at the knee noted, January 13, was more marked. There was a rounded, tense, fluctuating tumor about 2 inches (5 cm.) in diameter just below and internal to the patella. It was not painful, tender or reddened and did not pulsate. Flexion of the knee was limited to about 20 degrees. The patella was floating and could be balloted. There was slight lateral mobility of the knee joint, but no crepitus. The patient had no fever. Examination suggested effusion into the knee joint.

January 28: Roentgen-ray examination revealed considerable swelling of the soft parts on the inner side of the left knee. The lower end of the femur appeared to be fairly normal. The patella was normal in appearance and position. The joint space was considerably increased in width. There was almost complete destruction of the inner side of the head of the tibia, extending down the shaft approximately 6 cm. The cortex in this area had been destroyed, and there was no evidence of any bone production. Extending into the soft tissues was a rather diffuse, hazy area of increased density. The lateral view was negative except for some joint haziness. Diagnosis of sarcoma of the inner head of the tibia, of very malignant type, was made (Fig. 12).

January 28: A distinct pulsation was demonstrated in the tumor. By aspiration, about 5 c.c. of blood was obtained with difficulty. Culture of this blood showed *Staphylococcus aureus.*

January 29 (Note by Dr. J. M. Flint): "The patient when seen just after admission for refracture of the soft callus showed nothing abnormal about the knee. His leg was taken from the cast by the present observer and the mobility

at the site of the fracture elicited. The record of the onset of the present condition is in Dr. Smith's note. There is marked swelling over the inner aspect of the knee, beginning at the internal condyle of the tibia, 5 cm. below the tuberosity and extending up above the patella. The tumor measures approximately 15 by 20 cm. It extends backward to the edge of the popliteal space. This is soft and elastic and pulsates distinctly on pressure. Compression of the femoral artery stops the pulsation. Aspiration withdrew blood with difficulty and it clotted immediately. There is no bruit or thrill, over the most prominent part of the tumor. The roentgen ray shows a clean cut erosion of the entire internal condyle of the tibia which just escapes the joint surface.

Fig. 12 (Case 3).—Destructive process of the upper inner condyle of the tibia. There is no evidence of giant cell tumor.

There is apparently no effusion in the joint. Roentgen-ray examination shows no abnormal separation of joint surface or elevation of the patella. There is no periosteal reaction or new bone production. The picture does not look like a bone cyst but more like an extremely rapidly growing endosteal sarcoma."

January 31: The limb over the most prominent portion of the tumor measured 36 cm. in circumference at a point 3 cm. below the lower edge of the patella. The pulsation was even more apparent than before. Aspiration withdrew blood which clotted but did not appear to be in an open cavity.

Operation (February 3): Dr. Duffy performed midthigh amputation. The growth, which was cut down upon, appeared to be just below the internal lateral ligaments of the knee, and was quite cellular in appearance; obviously, a malignant type of sarcoma.

March 17: The patient had been about in a wheel chair for several weeks. There was a very slight bloody discharge from the lateral end of the scar. The patient's condition was greatly improved, and he was discharged.

June 1, 1923: The patient was alive and well, and had had no trouble since amputation.

Pathologic Examination.—In the head of the tibia just below the articular surface of the knee joint was a large mass about the size of a baseball. Its largest transverse diameters were about 5.5 by 7 cm. The specimen was fixed in Kaiserling's solution by injection through the popliteal artery and had well preserved color. The tumor appeared to be well encapsulated except where it was invading the bone, and there the advancing edge was rather diffuse. The tumor was practically against the popliteal vessels, only 1 or 2 mm. of tissue separating them. The color was a yellowish brown mottled with hemorrhagic areas from pinpoint size to 3 cm. Several cystic areas measured up to about 3 cm. in diameter and were filled with gelatinous material. The specimen did not have the appearance which is understood to be usual in the benign giant-cell tumor and did not resemble currant jelly so far as I was able to determine. The tumor had destroyed the head of the tibia and pressed upward directly on the cartilage of the knee joint (Fig. 13). A number of specimens were taken for microscopic study.

Grossly, one would not expect the presence of a great deal of fibrous tissue, and the impression, as at operation, was that the growth was malignant.

Microscopic examination: The capsule was very thin, varying from 0.1 mm. to 3 mm. in thickness, and composed of fibrous tissue. No place was found where it was definitely broken through, although there was some infiltration of its inner layers in a few places. A few fragments of cartilage were seen; often in relation with the capsule, sometimes isolated in the interior of the neoplasm.

The striking features of the tumor when viewed under the lower power were (1) the number and relatively uniform distribution of the giant cells, which are of the typical epulis type, and (2) the marked vascularity shown by the presence of numerous capillaries, sinuses, venules and occasional larger vessels, up to 5 mm. in diameter. In the case of one of the last, the close relation of the tumor cells was evident. These could be seen infringing on and in masses jutting into its lumen. The circumscription of the mass of red blood cells in the latter argued against this being a hemorrhage. Elsewhere, a number of hemorrhages were to be seen, and in several instances these were in various stages of organization by young cells of the fibroblastic type, rather myxomatous often times in appearance.

The small blood sinuses which dotted the low power field were similarly in close relation with the surrounding stroma or giant cells, which occasionally seem definitely to compose the sole limits of such blood spaces.

The giant cells seemed of the type characteristically present in the benign giant-cell tumors. But it is well established that the question as to whether these tumors are benign or malignant must be largely determined in each instance by the growth propensities of the cells of the stroma (i. e., the cells between the giant cells), as manifested by their appearance of malignancy or benignancy. In this case, the growth was at first considered benign; but on further study of the stroma cells, there was evidence that the stroma was more active than in the typical benign tumor: there were (1) the increased vascularity and intimate relation of tumor cells with the lumina of blood vascular spaces; and (2) occasional mitoses present in the stroma.

The stroma varied from a tissue composed of rather mature fibroblasts to one in which fibroblasts were quite young, and cells approaching the type characteristic of spindle and round cell sarcoma were found. In these areas, the structure was rather similar to that in a case of "malignant hemorrhagic

Fig. 13 (Case 3).—The tumor extends to the joint cartilage above and rests posteriorly on the popliteal vessels. There are cystic areas in the tumor.

bone cyst" reported by Bloodgood[6] and shown in Figure 23 of his publication on "Bone Cysts, Benign and Malignant."

In places, medium or large polygonal cells containing large numbers of unstained highly refractile granules were present in considerable numbers.

6. Bloodgood, J. C.: Proc. Alabama M. A., 1919.

These were identified as the so-called xanthoma cells which Ewing[7] has noted as occurring in giant-cell tumors, or sometimes as the chief type of cell (xanthosarcoma). This feature must be counted a relatively unusual one; although possibly when present only in small numbers, they may be overlooked (Fig. 14).

A diagnosis was made of giant-cell tumor of borderline type, with areas of xanthosarcoma, possibly malignant.

From a clinical standpoint, this patient presented a most confusing problem. While in a plaster cast, under treatment for a fractured femur, he developed a tumor near the knee joint which, in spite of the splinting, grew quite rapidly and pulsated. Pulsating bone tumors are as a general rule of malignant character (bone aneurysm of Bloodgood; telangiectatic sarcoma of Ewing). Bloodgood[8] states, however, that pulsation occurred in a giant cell tumor operated on by Halsted some years ago. The roentgenogram in our case, also, revealed a destructive process which completely eroded the upper inner portion of the tibia. The rapid course, the pulsating character, the roentgenogram, the cellular appearance at operation, and especially the vascularity —all favored a malignant process. We did not appreciate until after the specimen was dissected that the pulsation was probably entirely transmitted because of the relation of the popliteal. The fact that this patient had a four plus Wassermann reaction may have had some influence on the course of the tumor.

The pathology is interesting. The neoplasm seems definitely a borderline case between benign and malignant. It is a variant of the giant cell tumor, atypical in its marked vascularity and presence of xanthoma tissue (xanthosarcoma?). Ewing[7] states that this feature when associated with the giant-cell tumor usually indicates a more progressive tumor. All of these facts seem to correlate fairly well with the clinical history and physical findings.

Amputation was performed in this case because the process was thought to be malignant. In view of subsequent study, a frozen section diagnosis based on a single fragment of tumor would have given little aid and might have been a positive disadvantage if a relatively acellular area had been chosen. It is an open question whether or not amputation is indicated when a benign giant-cell tumor practically encroaches on a weight-bearing joint. Ewing has questioned the curetting of such tumors as he has seen quite a number of infected useless joints following this procedure. Such a sequel would indicate faulty operative or dressing technic, and without doubt the dead space is largely responsible for such an outcome. Resection and grafting seem to be a more logical

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7. Ewing, James: Review and Classification of Bone Sarcomas, Arch. Surg. **4**:485-533 (May) 1922.

8. Bloodgood, J. C.: Ann. Surg. **52**:175-176, 1910.

choice for this class of case and weight-bearing could be handled by a walking caliper splint. From an economic point of view, amputation is the best short cut available.

CASE 4.—*History.*—L. C., a boy, aged 2½ years, admitted to New Haven Hospital, Feb. 13, 1917, with the complaint of tumor of the right thigh, and whose

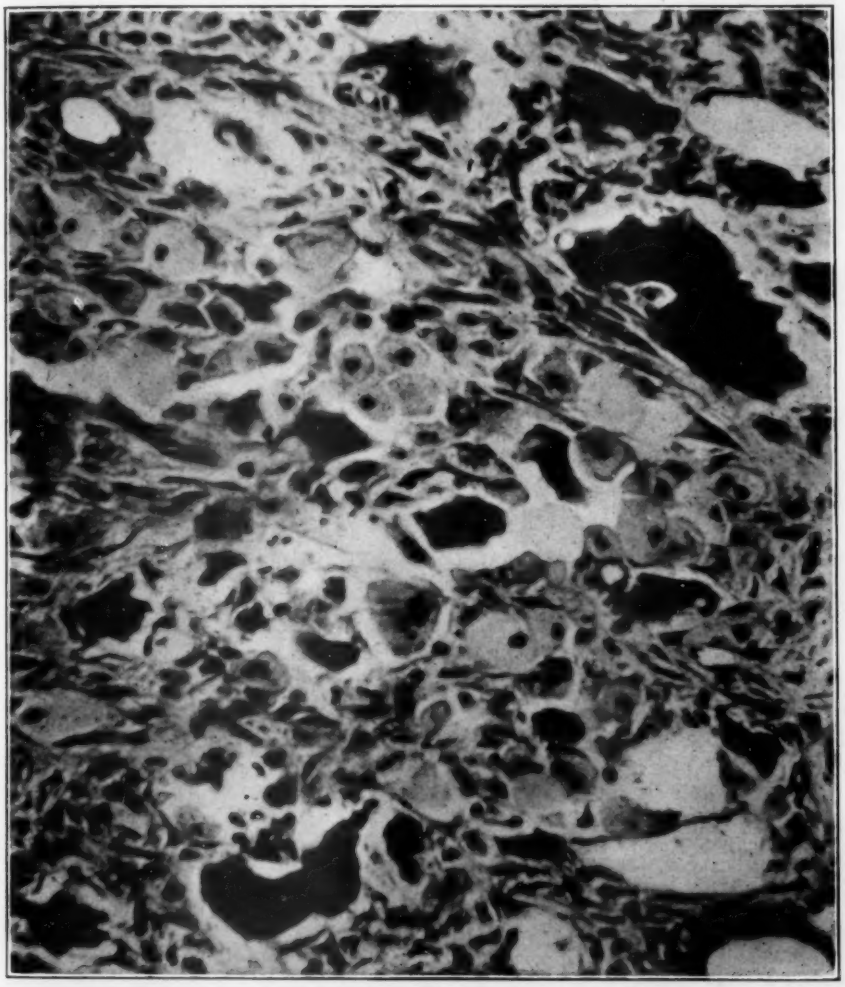

Fig. 14 (Case 3).—Numerous large cells with clear cytoplasm, containing refractile lipoid granules which are not here apparent, are present throughout the central portion of the photomicrograph. These are the so-called xanthoma cells. (Nuclei of giant cells retouched.)

family and personal history were unimportant, four months previously (November, 1916), fell on the floor and struck his leg. His mother noticed a small swelling on the lower part of the right thigh and took him to a physician for

treatment. The swelling went down somewhat but did not disappear entirely. One week later, the boy seemed well and was able to walk. Two months previously (January, 1917), he fell again, and the leg reacted as previously. February 8, five days before admission, he fell a third time, as if the leg were weak. The swelling became much greater and he was taken to Gaylord Farm for roentgen-ray examination. On entry, the boy was unable to walk and cried out as if in pain. The swelling seemed to be increasing in size and was tender. The child had always been well except for this illness.

Physical Examination.—This was negative except for the local condition. The right thigh presented a definite tumor at the lower half above the knee. There was no reddening or evidence of inflammation, although the surface temperature was increased. The tumor was firm and did not give an egg-shell crackling on pressure. It extended up to the middle of the femur. The knee joint was apparently free. The child did not appear to be particularly well nourished. There were a few palpable glands in the right inguinal region. Urine examination was negative.

On admission, the temperature was 99 F., the pulse rate, 100. Roentgen-ray examination revealed a markedly enlarged lower third of the femur just above the epiphyseal line. The cortical bone was thinned out. There were a few fine trabeculae within, dividing the growth into many chambers. The outer shell was markedly thinned at the medial posterior angle of the growth about 5 cm. above the epiphysis, and the tumor there appeared to invade the soft parts (Fig. 15).

Operation (February 15).—Amputation of right thigh was performed, through the middle third.

March 4: The patient was discharged from the hospital. The drains were all out, and the wound was clean. Healing was by first intention. There were no signs of inflammation. The general condition was good.

June 1, 1923: The boy was well, with no signs of malignancy.

Pathologic Examination.—Gross pathology (Fig. 16): The cystic structure began 0.5 cm. above the lower epiphyseal line of the femur and extended up the shaft of the bone for a distance of almost 7 cm. The shaft of the bone throughout the involved area was expanded to a maximal width of 4 cm.; whereas, the normal width of the shaft above the pathologic area is 1.5 cm.

The pathology was that of a multilocular cyst with smoothly lined cavities varying from a few millimeters up to 2.5 cm. in diameter. The cavities were lined throughout by a smooth surfaced wall, which varied in thickness from 0.5 mm. to 1.5 cm. In the Kaiserling and oil-preserved specimen, the color of the wall still remained to some extent, and varied from a dark yellow-gray to a reddish yellow. There were some blood clots present in the cysts, but the fluid content had escaped, leaving no record of its character. There was no apparently granular or friable tissue except blood clot, or any appearance which excited suspicion of malignancy. The diagnosis was benign bone cyst of the lower third of the shaft of the femur.

Microscopic examination: Sections from the cyst wall showed characteristic osteitis fibrosa tissue, in which there was a large amount of poorly developed or degenerating cartilage. This was laid down in the form of interlacing trabeculae, the interstices of which were filled with connective tissue of the fibroblastic type. There was no definite myxomatous tissue present. The picture presented resembled that in Bloodgood's[6] publication on bone cysts

(Fig. 12, page 21). Indeed, if one were not familiar with the roentgen ray and gross appearance of the area involved in this case, it would not be difficult to make the incorrect diagnosis of malignancy. The structure differed somewhat from myxochondrosarcoma. There were no mitoses and hyperchromatism was not striking (Fig. 17).

Fig. 15 (Case 4).—Many chambered cavity limited to the diaphysis, with a break in the cortex posteriorly.

It is interesting to note that the cartilage scattered through the wall of osteitis fibrosa tissue is at a distance of several centimeters from the epiphyseal line (Fig. 17).

Microscopic examination confirmed the diagnosis of benign bone cyst of the shaft of the femur.

The finding in a child of a central tumor in a long pipe bone following an injury would call for conservative procedures according to the knowledge that we have today. If, in addition, the roentgen-ray picture was that of a many chambered cavity sharply limited to the diaphyseal side of the shaft with the cortical shell well preserved or fractured, the most probable diagnosis would be benign bone cyst. Such a case calls for curetting or collapse of the cystic cavity, or even noninterference. In Case 4, all the foregoing features seem to point to such a conclusion,

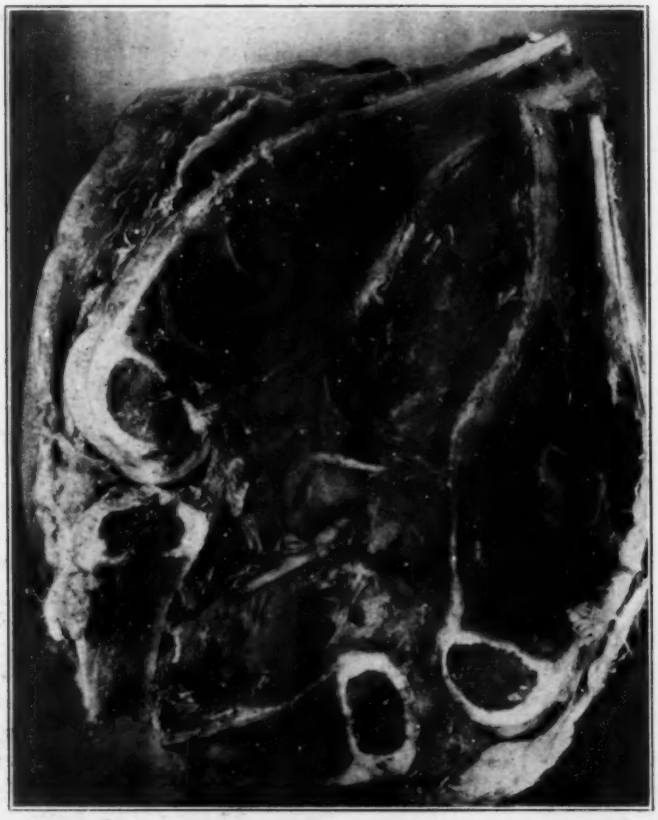

Fig. 16 (Case 4).—The multilocular cystic cavity with the expanded cortical bone at either side. The thin bone shell may be noted.

and yet amputation was performed. The clinicians must have been influenced by the run-down appearance of the child and the thinning out of the cortical shell posteriorly as shown by the roentgen ray. This was probably interpreted as invasion of the soft parts by the tumor. Such cases of malignancy in apparently benign bone cysts have occurred.[9]

9. Meyerding: Personal communication to the authors.

Bloodgood [10] states that, in a number of cases of bone cysts with osteitis fibrosa, a diagnosis of malignancy had been made from the frozen section. In none of Bloodgood's cases in children under 15 years was the subsequent course that of a malignant tumor, although in only one case had the operating surgeon proceeded on the diagnosis

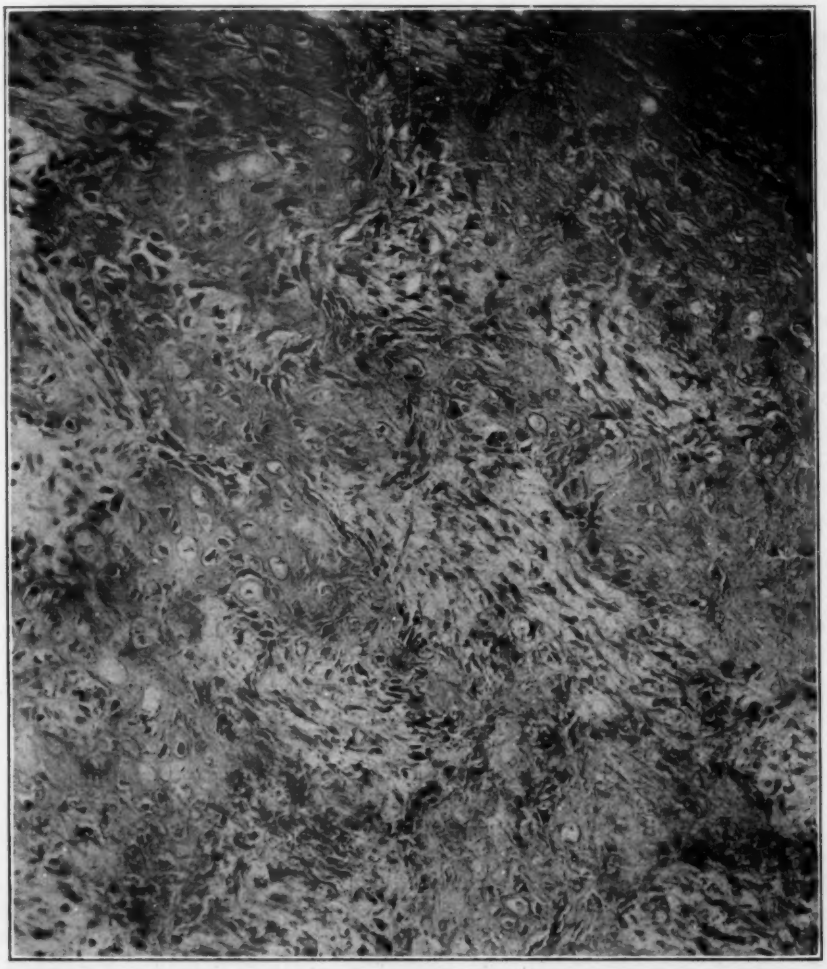

Fig. 17 (Case 4).—Cartilage trabeculae in osteitis fibrosa lining of cyst cavity; section from block taken several centimeters from epiphyseal line.

of malignancy from the frozen section, and performed an amputation. The danger of an incorrect microscopic diagnosis is great, unless correlated with the gross picture in this type of case.

10. Bloodgood, J. C.: J. Radiol. **1**:147-241 (March) 1920.

CASE 5.—*History.*—A. A., a boy, aged 8 years, admitted to the New Haven Hospital, May 21, 1915, with a complaint of pain and swelling of the right thigh, and whose family history and personal history was negative, three weeks previously (May 1) had been pushed by a boy and had fallen on a railroad track, striking the inner side of the right thigh against the rail. He thought the knee was injured, but walked home.

Physical Examination.—The general findings were normal. The local process consisted in a large round swelling, 10 cm. by 15 cm. in diameter, under the vastus internus muscle on the anterior internal aspect of the right thigh, 20 cm. above the patella. The mass felt hard and firm, with a slight amount of elasticity about the edges. There were no pulsations or thrills, and the popliteal artery was easily palpated.

Roentgen-ray examination revealed an elevation of the periosteum, with the shadow of either a large hematoma or an abscess, and nothing suggestive of periosteal sarcoma. The temperature was 98; pulse, 110; respiration, 20. The blood count was: white blood cells, 11,800; polymorphonuclears, 73 per cent.; lymphocytes, 22 per cent.; mononuclears, 4 per cent.; eosinophils, 1 per cent.

May 22: The swelling was aspirated and about 5 c.c. of fresh blood was obtained. A culture showed no growth.

The patient was not seen again till July 24, when the following note was made: "The tumor has increased considerably in size, now extending for some distance under the popliteal space, where it is quite firm and hard. A roentgenogram shows very distinct ossification of the periosteum around the upper and lower margin together with a little parallel striation which simulates sarcoma. There is considerable destruction of bony substance on the inner aspect of the thigh."

July 25: The patient was discharged, unimproved, against advice.

October 5: He was again admitted to hospital. The tumor broke down and became an open sore after he left the hospital. It increased rapidly in size up to two months previously, when the patient was forced to go to bed. Since then, the sore had not grown much larger, but the leg was quite painful.

On examination of the right leg, over the vastus internus muscle chiefly, almost midway between the knee and the thigh there were two ulcerated open wounds, approximately 10 by 8 cm. in diameter. There was a very foul discharge and no suggestion of formation of healthy granulations or indications of healing.

October 13: Roentgen-ray examination revealed pathologic fracture at the junction of the middle and lower third of the right femur. The lower half of the bone was swollen. The structure was more or less destroyed. The periosteum was thickened and elevated. The upper third of the bone seemed to be normal. Urinalysis revealed a slight trace of albumin. The Bence-Jones reaction was positive. Casts, pus, white cells and red cells were not found.

October 21: The Wassermann reaction was negative.

Operation (October 21).—Amputation of the right thigh was performed, incision being made on either side of the thigh. The tumor appeared malignant, and the condition was confirmed by frozen section. The leg was amputated just below the trochanter by circular incision, and was closed with a drain (Fig. 18).

October 30: The drain was removed. There was no infection. A dry dressing was applied.

November 23: The patient was discharged, the wound having healed.

September 21, 1916: The patient was admitted for a third time. Since leaving the hospital, he had remained well until within the last three weeks, when he noticed that the stump was gradually becoming swollen, although painless. He felt well otherwise.

Examination revealed: no mass in the abdomen; liver edge not felt; spleen not palpable; no evidence of involvement of lungs. A high thigh amputation of the right extremity had been performed. The scar was well healed. There was an uniform enlargement of the stump without tenderness. The skin was slightly reddened, and the superficial veins were dilated. There were no palpable glands.

Urine examination, September 23, was positive for albumin, but no Bence-Jones bodies were reported.

October 12: The patient was discharged to Dr. Coley in New York for treatment. The condition was absolutely inoperable, the roentgen ray showing that the growth had extended to the head of the femur and very probably beyond. We lost trace of this patient.

Pathologic Examination.—Gross pathology: It may be noted here that neither of us had any first hand or other information of the case except that contained in the foregoing history; and also that the frozen section from which the diagnosis of sarcoma appears to have been made originally evidently was not preserved, and there was no positive evidence of tumor in celloidin sections of the original blocks.

The museum specimen consists of one half of the bisected lower three-fourths of the femur, with the upper one fourth of the tibia attached. The color was not well preserved (Kaiserling's solution and oil).

The soft parts over the fracture (Fig. 19) were swollen and involved by two large irregular ulcerations 6 and 4.5 cm. in diameter, respectively, and separated by a narrow bridge of skin and subcutaneous tissue. The ulcerations were deeply excavated (to a depth of 1 cm.), but the skin edges are not undermined.

The cut surface of the femur showed an increase of the normal antero-posterior bowing. At the point of greatest angulation, no definite fracture was seen in the half of the bone at hand. The periosteum was intact throughout, but beneath it on the posterior surface of the femur there was a zone of new growth of bone resembling normal callus which extended 6 cm. to either side of the level of the point of greatest angulation. Near the upper limit of this callus, it was softer and had a slightly moth-eaten appearance.

The medullary canal of the bone appeared to be obliterated for a distance of 6 cm. This appearance was due apparently to a sclerotic process rather than to the section having missed the medullary canal. This was confirmed by dissecting away the periosteum and comparing the thickness of the bone here and elsewhere. Throughout this sclerosed area were small irregular clefts, suggesting an inflammatory process. No pus was encountered anywhere in the bone and no sequestration.

The specimen was divided transversely through the ulcerated area down to the shaft of the bone and the latter dissected away. The soft parts in the neighborhood of the ulcers suggested only an inflammatory process. One purulent collection 1 cm. in diameter was found just below the base of an ulcer.

The periosteum was found to strip easily from the bone, leaving a surface of moth-eaten appearance, involving the entire convex surface of the lower one half of the shaft. On incising a small prominence in the soft parts just over the periosteum, we were surprised to expose the cut surface of what appeared to be a tumor nodule 1.8 by 1 cm. This area was soft, gray with red mottling

and slightly granular on the cut surface, resembling somewhat a lymph node, save that its periphery was slightly convoluted and its surface a trifle granular. It resembled malignant tissue and lay immediately upon the periosteum, but seemed distinct from the latter.

In résumé, it may be stated that until the nodule described above was found, more or less by chance, the gross appearance seemed to be essentially that of a low grade chronic osteomyelitis.

Fig. 18 (Case 5).—The gross specimen showing angulation of the bone and increased bone formation with a posterior periosteal reaction.

Fig. 19 (Case 5).—Roentgen-ray appearance of specimen shown in Figure 18. The bone appears moth-eaten. There is a fine shadow of new bone posteriorly.

Following miscroscopic examination of the previously described nodule which in the gross gave suspicion of malignancy, we again examined the gross specimen, for we had as yet secured no evidence of malignancy in the bone itself. The nodule referred to above came from outside the periosteum. Blocks were accordingly secured from the soft, crumbly, rather reddish tissue beneath the periosteum, about 4 cm. above the location of the nodule. This tissue had been inspected before and classified as normal or infected, rather vascular or hemorrhagic callus.

With regard to the question of fracture of the femur as shown by the roentgen ray, we must note that, on bending the stripped femur, we were unable to secure any false motion.

Microscopic Examination: A section from the soft parts and ulcerated area of the thigh showed only chronic and subacute inflammatory changes. The usual pyogenic inflammatory exudate was present, with no evidence of tuberculosis or syphilis. Toward the ulcerated surface of the thigh, the picture of a vascular granulation tissue was especially marked. The ulcer surface was divested of epithelium.

The section examined contained portions of four separate blocks of decalcified bone. Histologically, these showed no definite trace of tumor formation. Sections from two of the smaller fragments showed some evidence of a chronic and subacute inflammatory process involving the periosteum as well as cortical and medullary bone. The lack of involvement of some entire blocks as well as the apparent histologic appearance seemed to indicate a nonfulminating, low-grade, chronic inflammatory process.

Sections of the suspicious nodule found lying on the periosteum showed a solid cellular growth composed of small polyhedral cells. There was no supporting connective tissue stroma for the great majority of cells, which lay free in sheetlike masses containing a few blood vessels and occasional delicate fibrous trabeculae. There were scattered areas of necrosis present involving small masses of cells 0.25 to 0.5 mm. in size.

The blood vessels present supported adjacent tumor cells which were rather consistently arranged radially from the smaller vessels. The character of the cells indicated a malignant tumor, as evidenced by fairly frequent mitoses, as many as three appearing in a single high power field. The tumor cells had very small amounts of clear cytoplasm and generally vesicular nuclei. The appearance was that of an endothelioma described by Ewing[7] as "diffuse endothelioma of bone" (Figs. 20 and 21).

Sections from the soft callus-like material and superimposed periosteum showed definite malignancy of the same character as that noted above. The periosteum was infiltrated by the small polyhedral or round type of cell, and on the underside of the main layer of periosteum were large areas made up of similar cells. The only bone present consisted of small fragments within the layers of the periosteum itself or of fibrous trabeculae extending from the main periosteal layer (Fig. 22).

With regard to the tumor cells, we were again impressed with the lack of connective tissue stroma except in relation to the periosteum. Blood vessels were scarce in the tumor tissue, but it is an interesting fact that vascular spaces containing red blood cells occurred lying surrounded by tumor cells without any definite vascular walls.

The final diagnosis was endothelioma of the femur (the diffuse type of Ewing), apparently subperiosteal in origin, associated with fracture, chronic osteomyelitis and extensive chronic infection of soft parts and ulceration of skin. There was a mestastatic extraperiosteal nodule.

The difficulties in diagnosis are well brought out by a review of the history. On the patient's first visit to the hospital, three weeks after injury, there was a hard elastic swelling of the thigh and no signs of infection. The roentgen ray revealed a slight elevation of the periosteum and nothing else of note. Under the circumstances, a diagnosis of hematoma was warranted as there was nothing to indicate an actual

malignant process. The importance of a thorough followup is evidenced by the rapid progress of the growth in the two months after discharge from the hospital. The diagnosis of a bone tumor was established by the roentgen-ray picture and the clinical findings when the patient was seen the second time. Unfortunately, we could not find the roentgenogram in this instance; but a picture of the specimen after amputation shows a mottled destruction of the shaft, with a fracture, cortical thickening about this area and a fine deposit of subperiosteal callus posteriorly (Fig. 19). The surgeon explored the growth, considered

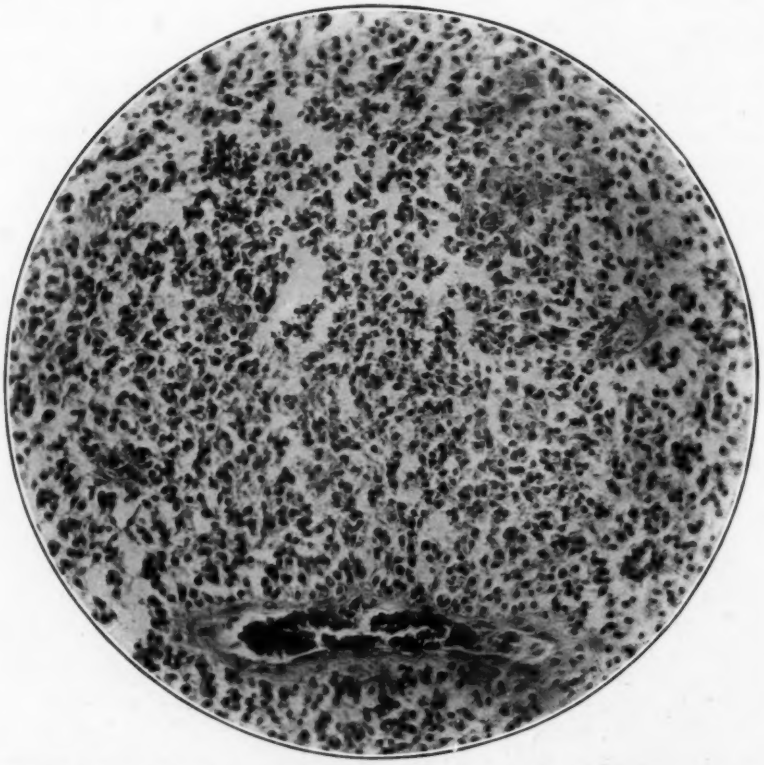

Fig. 20 (Case 5).—The small polyhedral or round cell with poor staining cytoplasm and absence of connective tissue stroma may be noted. The small blood vessel shows very closely associated tumor cells.

that the grayish islands of infiltrating tissue were sarcoma, and amputated. The frozen section confirmed the operator's judgment. The presence of two ulcerations of the thigh and infection, and the roentgen-ray picture, which might easily be interpreted as that of osteomyelitis, might offer another difficulty in differential diagnosis. The tumor mass with the induration of the soft parts would serve to rule out an infection of the bone, and the lack of a marked general reaction

would be an additional support. Bence-Jones bodies give further assistance, although not pathognomonic for bone tumor. If this tumor could have been diagnosed with accuracy as of periosteal origin, most of the modern writing would favor nonsurgical interference, but a course of radiotherapy. Coley would certainly advise the use of toxins as well. We feel that the pendulum is swinging perhaps a little too far toward conservatism.

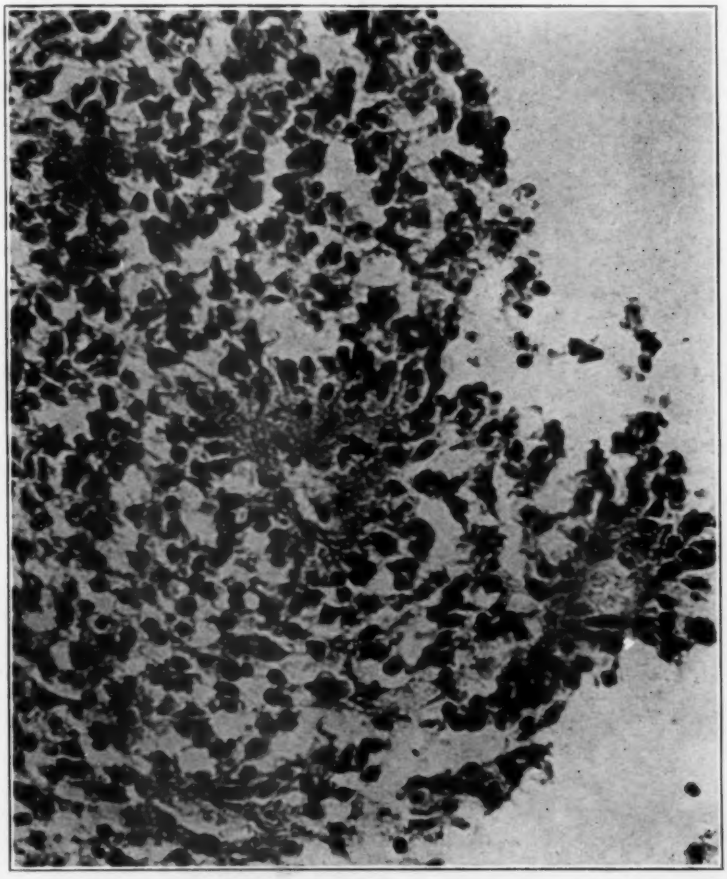

Fig. 21 (Case 5).—Radiation of cells from the small central blood vessel, which shows hypertrophy of its lining cells.

The questions as to the relation between the various manifestations of this case are by no means absolutely clear even in the light of the pathologic findings. 1. Did the tumor bear a causal relationship to the fracture which occurred? 2. What caused the extensive superficial ulceration opposite the point of fracture? 3. Was the infection of bone and periosteum related to the fracture? 4. Was the latter a compound

fracture? 5. Could there have been a subperiosteal infection dating from the time of the primary injury when no fracture, but only elevation of the periosteum, was determined roentgenographically? 6. Was the malignant process present before the original injury noted in the clinical history?

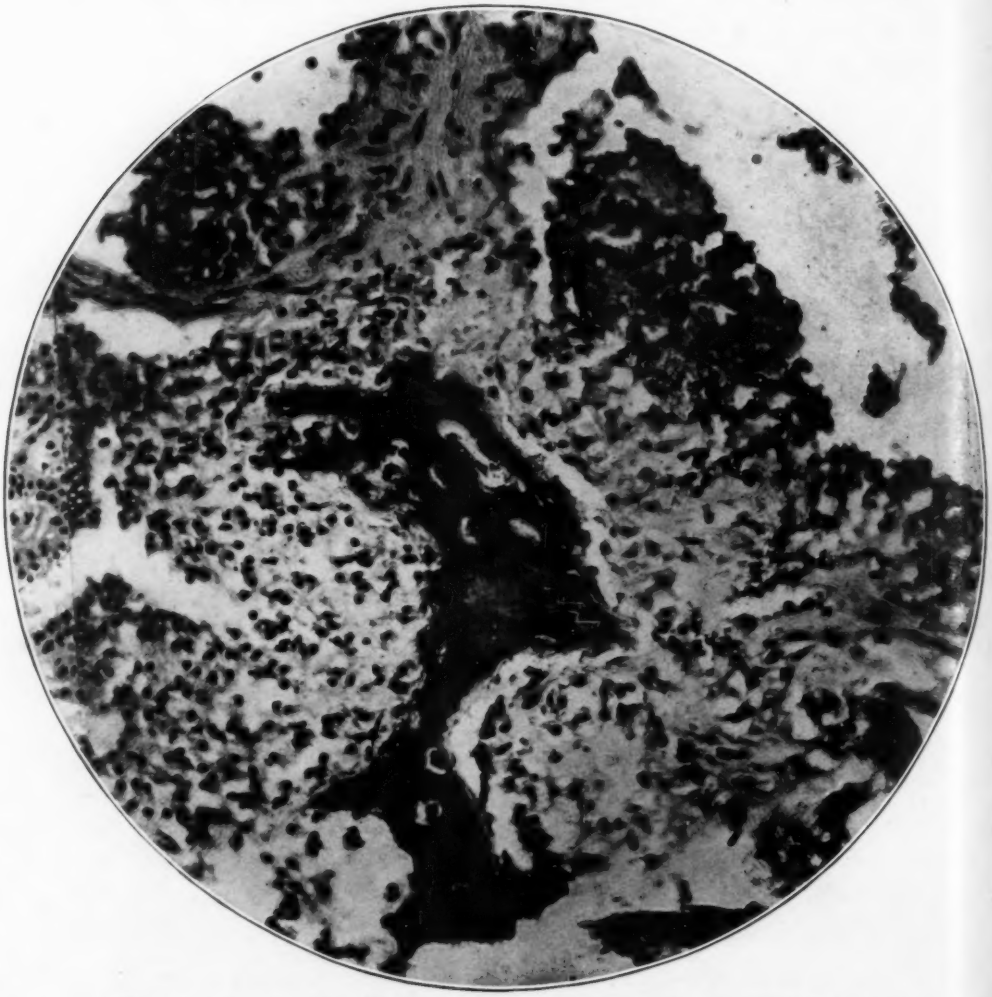

Fig. 22 (Case 5).—An island of periosteal bone partly surrounded by tumor cells.

These questions involve both clinical and pathologic data, many of which are lacking. With regard to the pathologic findings, we may in brief review these questions.

From the lack of extensive involvement of the shaft of the bone as determined by gross and microscopic examination, the tumor probably

did not cause the fracture. The demonstrated involvement by neoplasm was chiefly in a narrow zone beneath the periosteum. Also, it has been noted that firm bony union seems to have occurred.

With regard to questions 2, 3 and 4, it may be stated that, in view of the pathologic findings, it seems fairly reasonable to assume that the fracture occurred shortly after the patient's discharge from the hospital unimproved or about three months before his final admission. It seems improbable that the fracture was compound in view of the good union, with only slight angulation. However, infection might have been caused at this time by the injury (of which we have no knowledge) that caused the fracture. It was then that the ulcers appeared and continued to enlarge. We have no means of knowing what rôle his treatment at home may have played.

With regard to Question 5, there is evidence that there was quite a swelling (10 by 15 cm.) present three weeks after the original injury (less than six months before operation). At this time, elevation of the periosteum was noted, and hematoma or abscess was suspected from the roentgenogram. Instead of gradually subsiding, the swelling steadily increased in size, for, two months later, the swelling (which it may be recalled had been determined pathologically to consist largely of inflammatory tissue, and with absolutely no tumor tissue "breaking down"—the clinical interpretation) had "increased considerably in size, now extending . . . under the popliteal space where it is quite firm and hard." At the same time, "destruction of bone on the inner aspect" of the femur was noted in the roentgenogram.

From the foregoing facts, we feel that both inflammatory and neoplastic processes must have become active within a few weeks after the original (?) injury, or at any rate the injury which first directed attention to the thigh.

It seems impossible to say whether the malignant process antedated the original injury as noted in the clinical history. The apparent association of a low grade osteomyelitis with endothelioma of bone is a most interesting one. Ewing [7] states that "competent observers firmly maintained" that some of his cases were osteomyelitis. But in the case under discussion, we have microscopic evidence of osteomyelitis, in association with the tumor which seems to us very similar in its histology, clinical course and roentgenographic appearance to the type of lesion so ably described by Ewing as diffuse endothelioma of bone. Possibly the case we report is unique in having a proved associated infective element.

The tumor described is one which many pathologists still might call a small round-cell sarcoma. Its histologic and roentgenographic characters seem to resemble very closely the diffuse endothelioma of bone

described by Ewing. In this connection, we are glad to express our appreciation of his efforts at clarifying this little known entity.

CASE 6.—*History.*—E. P., a railroad laborer, aged 20, admitted to the New Haven Hospital, Nov. 8, 1920, with a complaint of pain in the right shoulder, about ten weeks previously was lifting heavy stones, his usual occupation, when he felt a sharp pain in the shoulder. He continued with his work, but the pain persisted. This continued for several days, when he consulted a physician, who gave him a liniment. This did not help him. About four weeks before admission, there was tenderness in the shoulder, but no noticeable swelling and no elevation of temperature. There was loss of motion, particularly abduction. The arm was put in a Sayre bandage, which relieved the pain. Six days before admission a swelling was first noticed. It gradually increased in size. The patient had a fever on the day of admission.

Physical Examination.—The patient, a well developed, well nourished man, lay quietly in bed, seemingly suffering no pain. There was no enlargement of the glands of the neck. The points of interest centered in the local examination. The right shoulder was definitely swollen and was held lower than the left. The skin covering it was normal in texture and moist. The surface temperature was higher than on the opposite side. The shoulder showed evidence of strapping with adhesive, and over the scapular region and on the back there was a marked papulopustular eruption where the strap had been fastened. The enlargement of the shoulder was globular and smooth and firm to the touch. It involved the head of the humerus completely. The clavicle and acromion seemed to be unaffected. The insertion of the pectoralis major and latissimus dorsi could not be palpated, seeming to enter the hardened mass. The glands of the axilla were not enlarged or tender. There was, however, exquisite tenderness on deep palpation over the whole of the enlargement. Motion of the arm was limited in all directions. The patient complained of pain on slight pressure and abduction of the arm. Measurements were: around the shoulder from axilla over acromion, right, 18 inches (45 cm.), left 14½ inches (36.3 cm.); neck of humerus, right, 11½ inches (28.8 cm.), left, 10 inches (25 cm.); at epicondyles of humerus, right 8½ inches (21.3 cm.), left, 8½ inches.

There was no impairment of the muscular action of the forearm or fingers (Fig. 23).

November 10: The tumor was aspirated. A few drops of bloodlike fluid were obtained. It was sent to the laboratory for culture. Later, the swelling was again aspirated and the needle pushed against the bone in two places. About 20 c.c. of dark blood-stained fluid which clotted very slowly was obtained. A smear of this fluid showed no organisms when stained with methylene blue and carbol fuchsin. With blood stain, it showed ordinary white blood cells. No red cellular débris and no tumor cells were found.

November 12: The culture from aspirated fluid was reported negative.

November 15: Dr. Duffy reported that sections of clot of aspirated fluid showed no tumor cells.

November 16: Measurements were: round shoulder, axilla over acromion, right, 19½ inches (48.7 cm), left, 14½ inches (36.3 cm.).; around neck of humerus, right, 14 inches (35 cm)., left, 10 inches (25 cm.)

Roentgen-Ray Examination (November 8).—The soft tissues of the shoulder particularly on the upper and outer portions showed some enlargement. The glenoid cavity and bone of the scapula surrounding the cavity were increased

in density, somewhat hazy and irregular. The anterior head of the humerus and upper portion of the humerus showed some irregularity and haziness in outline. There seemed to be a definite area of destruction in the outer portion of the head. The cortex in this position had been destroyed. On the inner side, opposite and just below the glenoid cavity, there are two areas of rather decreased density. There was also an area on the inner surface, 9 cm. from the upper end, in which the cortex had been destroyed and the medullary cavity appeared to be somewhat mottled. The lower half of the humerus appeared to be normal (Fig. 24).

Fig. 23 (Case 6).—Appearance of patient on admission to hospital.

November 12: Examination of the chest was negative. Repeated examination of the shoulder showed approximately the same condition, with some slight advancement.

The diagnosis was: acute destructive process, probably malignancy, although the picture is atypical; probably medullary sarcoma of the round-cell type.

November 19: The blood was typed as of Group IV.

Operation (November 19).—Dr. Flint performed an interscapulothoracic amputation of the right shoulder, by Le Conte's method.

December 11: The wound healed and the patient was able to be up. He complained of some pain in the region of the scar and constant severe pain referred to fingers of the amputated limb.

December 20: The patient was discharged. He was feeling well and his general condition seemed very good. He had slight pain at times in the scar. There were three small areas not covered with epithelium.

Vital Signs.—The patient entered the hospital with a temperature of 101 F. and a pulse of 105. Respirations were 20. The fever for the first week remained

Fig. 24 (Case 6).—Destruction of head of humerus and dense shadows in the soft parts.

constantly elevated above 100 F. and reached a point as high as 104 F. It was practically of a continuous type. The pulse rate gradually fell during the first week from 110 to 80. During the second week of his stay previous to operation, the temperature was of an intermittent type, going from normal to 102 F., and dropping back to normal. The pulse rate remained constantly at 80. Following operation, there was a slight postoperative rise in temperature and pulse, with a gradual subsidence to normal, which continued throughout the remainder of his stay in the hospital.

Laboratory Findings.—Urine examination (on two occasions) revealed nothing of importance except a slight trace of albumin and an occasional hyaline cast. Test for Bence-Jones bodies on two examinations were reported negative.

Blood examination, Nov. 9, 1920, revealed: white blood cells, 21,800; polymorphonuclears, 77 per cent.; large mononuclears, 10 per cent.; small mononuclears, 13 per cent.

November 11: White blood cells numbered 14,600; polymorphonuclears, 81 per cent.; large mononuclears, 9 per cent.; small mononuclears, 10 per cent.

November 16: The white blood cells numbered 9,800; polymorphonuclears, 75 per cent.; large mononuclears, 9 per cent.; small mononuclears, 14 per cent.

The Wassermann reaction, November 9, with alcoholic and cholesterinized antigens, was negative. Culture from aspirated fluid showed no growth.

Pathologic Examination.—A huge tumor about the size of a grapefruit, involving the upper end of the humerus, had broken through the head of the humerus at the point indicated by the roentgen ray. The tumor was very vascular in certain places, but there was not so much blood in it as would be expected from the aspiration.

The specimen was divided longitudinally. Similarly, the humerus itself was split and the medullary cavity of the latter was found to be filled with tumor almost the entire length. There was also a pathologic fracture of the upper third (Fig. 25). In spite of the presence of fracture, there was no expansion of the shaft. The absence of this feature, with preservation of the cortical bone everywhere save in small areas, together with the radiate arrangement of much of the tumor tissue from the periosteum, indicated that we were dealing with a periosteal rather than a medullary neoplasm. Many blocks were taken for microscopic study. The blood vessels were dissected out and the axillary vessels were found to be compressed. The axillary glands were greatly enlarged, some of them being suspicious, but there was no positive gross evidence of lymphatic involvement. Marked dilatation of the collateral blood vessels was noticed in one area.

Microscopic examination: A preliminary section was diagnosed spindle-cell sarcoma. In all, fifteen blocks were taken and sections from these were studied microscopically. The growth was a spindle-cell sarcoma, with slight tendency to the round-cell type in places. The latter areas, however, were rare, and throughout the greater part of the tumor the characteristics conformed rather clearly to the spindle-cell type. Mitoses were fairly numerous, perhaps slightly more so in the areas with round-cell tendency. A striking feature was the degree of vascular involvement by the tumor cells, which in many places composed the wall of the vascular spaces, definite tumor cells encroaching on the lumen of the vessel (Fig. 26). In one place, a large cell containing a mitotic figure was seen free within the lumen of the vessel. Sections of the axillary lymph glands showed no definite metastatic involvement, although one gland had a suspicious area, which was by no means definite sarcoma. A striking thing about the appearance of the lymph glands was the degree of vascular dilatation. This was probably the result of collateral circulatory changes.

The final diagnosis was: periosteal spindle and round-cell sarcoma.

Second Admission (December 25).—The patient returned to the hospital four days after his discharge because of pain across the upper abdomen and sometimes in the left lower chest. He attributed this to overeating. He had a temperature of 103 F. on admission, but the temperature fell and reached normal four days after entrance and he felt much better.

Examination showed dulness over the lower third of the left side of the back. This did not extend into the axilla. Fremitus was slightly diminished over the lower left side of the back as compared to the right. No change in the breath or voice sounds was noted, and there were no râles. Elsewhere, there were

normal resonance and breath sounds, and no râles. The incision of the old operation was well healed, except for two small spots where epithelization was not complete. At the root of the neck on the right, there was a small area about the size of a quarter, which was sensitive even to very light pressure. Otherwise there was no tenderness about the scar. There was no induration. The white blood count, on admission, was 16,000. The urine was negative except for albumin.

Fig. 25 (Case 6).—From a drawing of the specimen removed at operation. The lack of expansion of the bone shaft and the apparent periosteal origin are evident. The fracture of the shaft is shown. The deceptive circumscribed character of the very malignant growth may be noted. The axillary glands (at right) were negative microscopically.

The patient was discharged ten days after admission. The temperature and pulse reached normal on the fourth day after admission. The impression was that the fever was caused by a small patch of bronchopneumonia.

When this man entered the hospital, he had a tumor mass which had all the earmarks of a rapidly developing malignant growth. The clinical course, roentgen-ray findings and pathology all conformed to type in this instance. The patient had fever, which usually indicates the rapidity of the tumor growth; and a further evidence was the local

Fig. 26 (Case 6).—Vascular spindle cell sarcoma with invasion of blood sinus by tumor cells at right lower center.

heat, which argues for active vascularity. We would not attempt so radical an operation today from our present knowledge. These osteogenic growths in young people, especially when the upper humerus is involved, give a hopeless prognosis by operation. The pathologic

picture, which shows malignant cells lining blood spaces, proves how futile it is to expect that metastases have not already established themselves. It has been stated that it is often impossible to say definitely whether a given bone tumor originated as a periosteal or as a medullary growth. The gross pathologic process in this case indicated rather definitely a periosteal origin but the growth did not present the typical radiating bony spicules in the roentgenogram. The very rapid progress probably gave no time for the formation of bone.

CASE 7.—*History.*—G. K., a man, aged 59 years, was admitted to New Haven Hospital, Aug. 9, 1920, with the complaint of pain and swelling of the right leg, which developed three years previously (1917), when he stepped from a street car and turned the right ankle. At this time, he felt a sharp pain in the lower part of the leg, and a few hours afterward, the leg became swollen and painful. He was unable to use the leg at all for a week. For two weeks, he used crutches. The leg did not bother him after that, although it felt somewhat weaker than formerly. Three weeks previously (July, 1920), while walking on the street, he felt a slight pain in the right lower leg. The leg gave way and he fell to the ground. He got up and was able to walk only with great difficulty. After the fall, the leg became swollen. The next day, he was seen by his physician, who applied a plaster splint. Roentgenograms of the leg were taken, and he was sent to the hospital for operation.

Physical Examination.—The general findings were normal. There was a swollen area about 7 cm. in diameter on the outer side of the right leg, about 7 cm. above the external malleolus of the fibula. This area was hard, tender and continuous with the shaft of the bone. It did not fluctuate.

Operation (Dr. Whittemore).—August 10, the growth on the right fibula was excised.

August 19: The wound was in good condition. There was very slight tenderness over the lower end of the wound in an area about 1 cm. in length. The ankle showed a small amount of swelling. The patient could move the foot in all directions without pain. There was no anesthesia of any part of the foot, and there was no limitation of motion in the ankle joint. The patient was discharged to his local physician for further care.

The vital signs were normal throughout the stay in the hospital.

Laboratory Findings.—The urine was negative. Blood tests revealed: white blood cells, 8,600; polymorphonuclears, 50 per cent.; large mononuclears, 4 per cent.; small mononuclears, 44 per cent.; eosinophils, 2 per cent. The Wassermann tests of the blood were negative to both alcoholic and cholesterinized antigens.

March 16: The patient remained well and reported that he had had no further trouble with the leg. His general health was good. He was able to get around as he had before, and the operative wound had showed nothing of note.

The original roentgenograms were not available. Roentgenograms of the tumor were taken, however, and revealed a destructive lesion of the bone, irregular in outline, extending up the shaft nearly to the line of incision (Fig. 28).

Pathologic Report.—Grossly, the specimen was a small tumor. It showed a portion of the fibula above and below a fusiform shaped tumor. On longitudinal section, the tumor was rather irregularly shaped and of a homogeneous, cellular appearance. The bone was replaced by tumor tissue at the midportion of the specimen, but apparently it did not extend into the bone on either end (Fig. 27).

Microscopic examination: Where the neoplasm lay adjacent to the soft parts, it appeared to have been growing essentially as an encapsulated tumor.

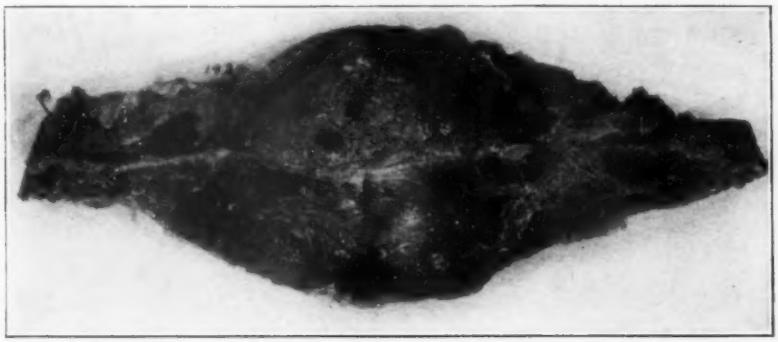

Fig. 27 (Case 7).—The external surface of the tumor, showing the periosteum apparently unperforated by the tumor.

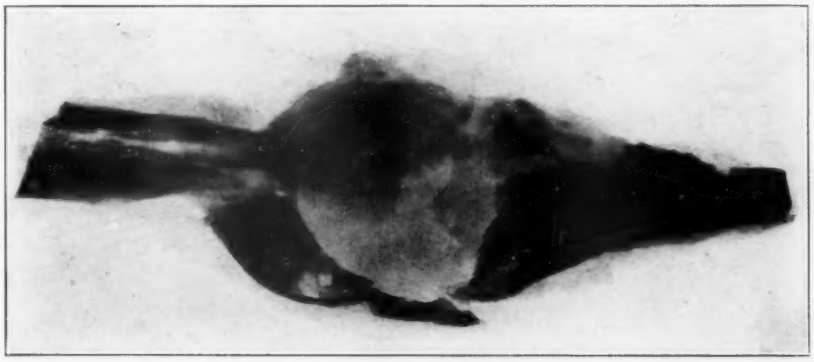

Fig. 28 (Case 7).—Roentgenogram of the excised tumor, showing a destructive process of the bone, with a fairly clear-cut edge in most places but small areas of infiltration in others.

In places, a definite fibrous capsule, varying in thickness from 0.25 to 1.5 mm., showed only a moderate degree of invasion by the cells of the new growth. The fibrous character of this capsule, its absence where the tumor was extending into the shaft of the bone, as well as the presence of striated muscle fibers in its peripheral layers suggested that it was either intact periosteum or else tendon sheath, probably the former.

As just suggested, the absence of encapsulation where the tumor was in contact with the shaft of the fibula was in striking contrast to conditions else-

where. Here, it was entirely without a connective tissue capsule, and its cells were seen to have extended along the haversian canals for a distance of 0.25 to 0.5 mm. Bone destruction here had progressed, without any new formation of bone.

Sections through the central portion of the growth showed a central, quite benign area, 1 cm. or more in diameter, composed of fibrous and myxomatous

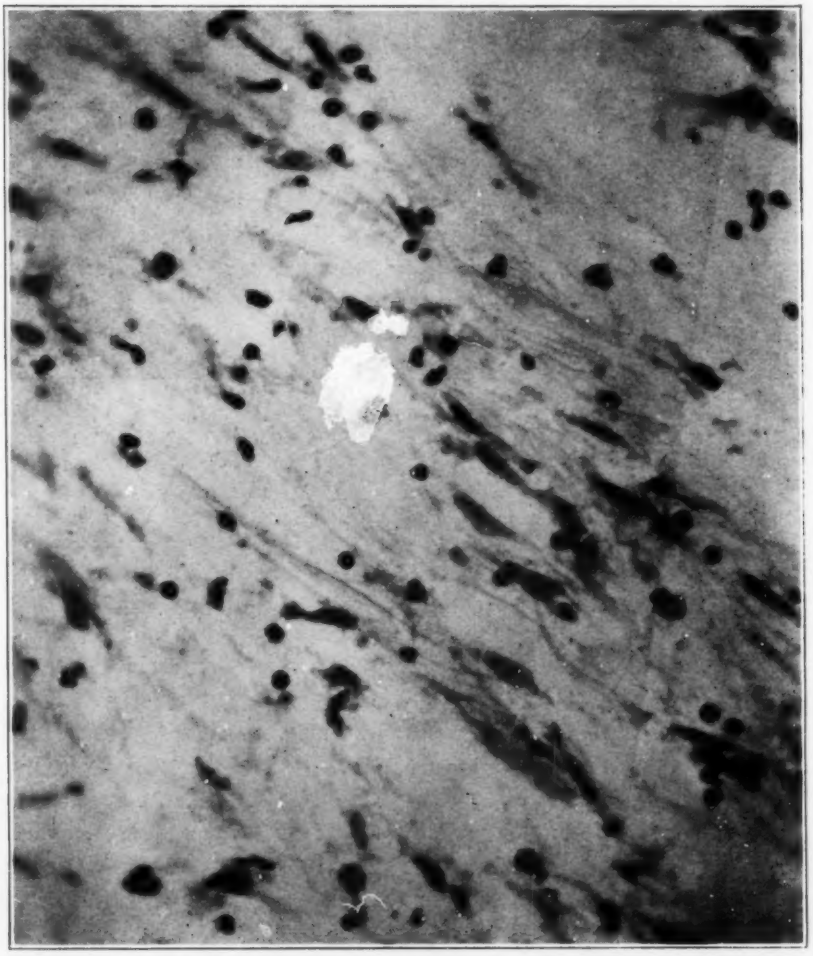

Fig. 29 (Case 7).—A myxomatous area from the central portion of the tumor. There are a few scattered lymphocytes throughout.

tissue, the latter predominating. Here, no mitoses were to be seen, and aside from a scattering of small lymphocytes, no other types of cells were seen (Fig. 29).

At the periphery, this fibrous and myxomatous area, shaded off rather abruptly into the main portion of the tumor, which consisted of spindle cells with relatively little fibrillar substance. Here, one saw a number of mitotic

figures, in some instances as many as five in a high power field, but in general they were few in number. There was relatively little fibrillar substance, and in places the tumor cells showed a slight transition from the spindle shape, becoming ovoid or round. Throughout the bulk of the tumor proper, there was not the hyperchromatism often seen in definite spindle-cell sarcoma (Fig. 30).

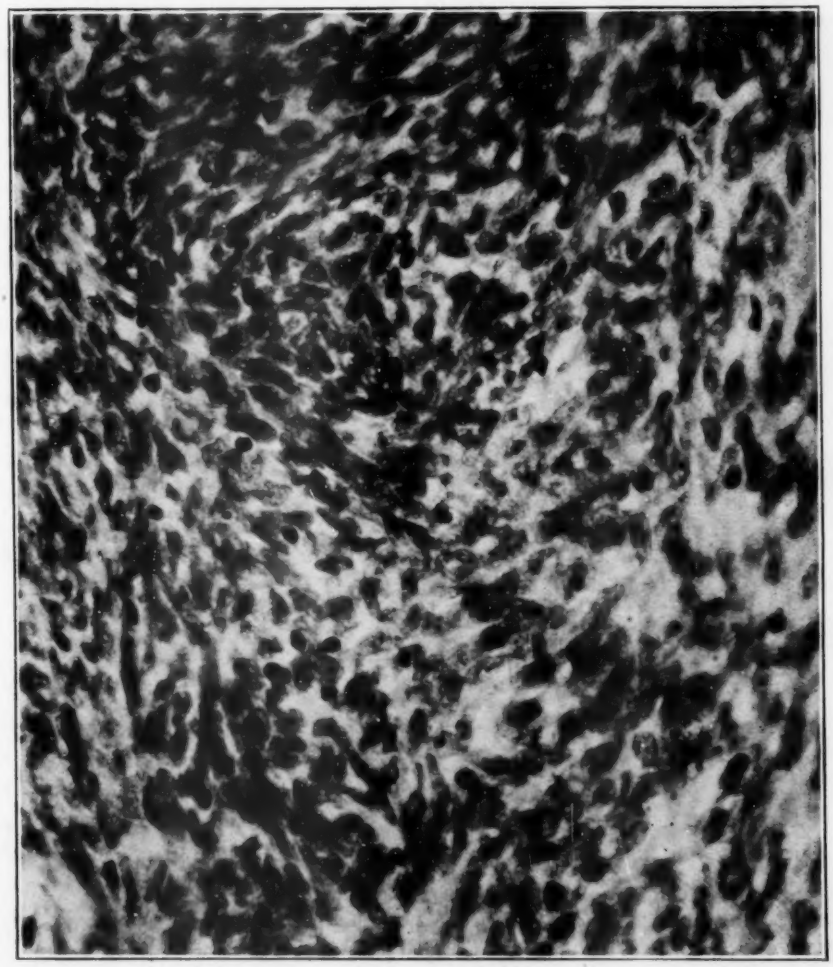

Fig. 30 (Case 7).—High-power photomicrograph of a cellular area; fibrosarcoma.

The relation of the tumor cells was a close one, and in certain areas there was evidence of actual obliteration of small vessels by the ingrowing tumor cells. The evidence of this was particularly striking in one small area where the wall of the venule was practically destroyed, but a few clumps of red blood cells persisted in what was left of the lumen. These were surrounded by ovoid tumor cells.

Giant cells of the epulis type were entirely absent. The only giant cells present consisted of a few osteoclasts in close proximity to bone which was being absorbed.

Only a trace of new bone formation was present in the "capsule" (periosteum?) overlying the tumor. This area was about 0.3 mm. in diameter. Elsewhere, no new bone was found.

One other histologic feature must be noted, the rather marked lymphocytic infiltration occurring irregularly throughout the tumor; sometimes diffuse and sparse, at other places definite small foci composed almost solely of lymphocytes. The significance does not appear obvious. There was a moderate diffuse lymphocytic infiltration in the capsule of the neoplasm.

We are dealing here with a tumor at the junction of the middle and lower thirds of the fibula, in a man of 59 years. The tumor may have been present for some time but gave little clinical evidence till three weeks before admission. The original roentgenogram could not be found, but a plate of the specimen showed that there was a destructive lesion which extended along the shaft both above and below the growth and almost completely eroded the main portion. There was scarcely any attempt at new bone formation. The edges of one side of this tumor were quite sharply demarcated from the cortex. From a frozen section, a diagnosis of malignancy was made: spindle-cell sarcoma. Nevertheless, the surgeon decided on a local resection and gave very little margin. In this, he had the backing of Bloodgood's opinion that, in a central lesion of the fibula, resection is the operation of choice. The result to date, two and one-half years after operation, has attested to the excellent judgment used.

In view of Bloodgood's experience with myxomatous tumors of bone, and his recent statement (1923) that "any bone tumor which contains typical myxomatous areas is for practical purposes as malignant as a sarcoma," this tumor should receive special consideration. Fortunately for study of the histology of the myxomatous tissue, the carefully preserved original frozen sections in this case, made at time of operation, are still available and show the undoubted area of pure myxoma.

It seems apparent that this neoplasm bears certain histologic earmarks of malignancy. That this is not of a high degree, however, is evidenced by the course of the case following local resection. If it were necessary to make a diagnosis from the microscopic examination alone, one would incline toward the side of malignancy. Otherwise, it seems that this was a borderline case.

We have here, then, a tumor which was taken early, as far as the clinical evidence is concerned; was diagnosed as malignant by frozen section; was removed by excision with a small margin, and yet the patient has remained well.

The diagnosis was osteogenic sarcoma, "solid medullary" (Ewing); probably the fibrospindle-cell-fibrosarcoma of Bloodgood (this latter term in Bloodgood's classification is taken to mean a slightly less malignant type than the "spindle cell sarcoma" of bone).

CASE 8.—*History.*—A. G., a girl, aged 16 years, entered the Hospital of St. Raphael, March 16, 1923, with the complaint of swelling of the right leg. For the past two years, the right leg had gradually increased in size just below the knee joint on the outer side of the leg. Except for the increasing deformity, there were no symptoms.

Physical Examination.—The general examination was negative. At the upper and outer side of the right leg, there was a fusiform swelling of bony hardness, 7 by 15 cm. in diameter, involving the upper portion of the fibula, with which it was intimately connected. There was a sense of elasticity but no fluctuation or egg-shell crackling could be made out. The tumor was not tender or inflammatory and did not pulsate. The overlying skin and subcutaneous tissues could be moved freely over the growth. There were no vascular or nerve changes.

Roentgen-ray examination revealed a spindle shaped expansion of the head and upper shaft of the fibula with a markedly thinned but intact cortex and delicate bony partitions traversing the expanded area (Fig. 31).

Operation (March 16).—Dr. W. F. Verdi performed a resection involving the upper third of the fibula, and the tumor. The muscles were very adherent to the tumor, which added to the difficulty of removal.

March 19: The patient died from pulmonary embolism.

Pathologic Report.—Gross Pathology (Fig. 32): The excised specimen after fixation in formaldehyd measured 14 by 5.5 cm. in the long and the transverse diameter, respectively. It consisted of an outer bony and cartilaginous shell representing the expanded and partly absorbed shaft of the upper third of the fibula. The bony shell of the tumor measured 0.5 to 3 mm. in thickness and crepitated slightly on pressure.

The interior of this shell bound cavity was filled with tumor material, which extended up to the cartilaginous surface of the head of the fibula and down the shaft nearly to the limit of the excised portion. Extension had occurred through the epiphyseal line, which was entirely obliterated save for a narrow rim lining the interior of the bony shell, about 2.5 cm. from the upper end of the bone. The center of the mass was occupied by cystic structures from 0.5 to 4 cm. in diameter, the contents of which had escaped. Several blood spaces containing clot appeared, up to 1 cm. in size. The cut surface, however, did not look very vascular in a diffuse sense, although the formaldehyd fixation may have affected such an appearance.

The greater part of the tumor was composed of solid cream gray tissue, which was rather soft in consistency. The cut surface was mostly smooth, but was somewhat granular in places. There were several discolored areas due to old hemorrhage, but no definite suggestion of xanthoma.

There was no definite gross evidence that the tumor had broken through the covering shell, although the latter was greatly thinned in places. No large vessels appeared to penetrate the bony shell. No bone trabeculae or areas of cartilage were to be seen on the cut surface. The gross impression was that the growth was probably a benign giant-cell tumor.

Microscopic examination: A thin layer of bone and cartilage varying from 0.1 mm. up to 1 mm. was seen on the peripheral side of the tumor section. This shell was being destroyed, as evidenced by the osteoid appearance of much of the bone, with evidence of absorption by osteoclasts. At intervals, there were apparent small interstices in the bony wall. One of these breaks in continuity was 1 mm. or more in width, and the vascular, rather fibrous peripheral portion

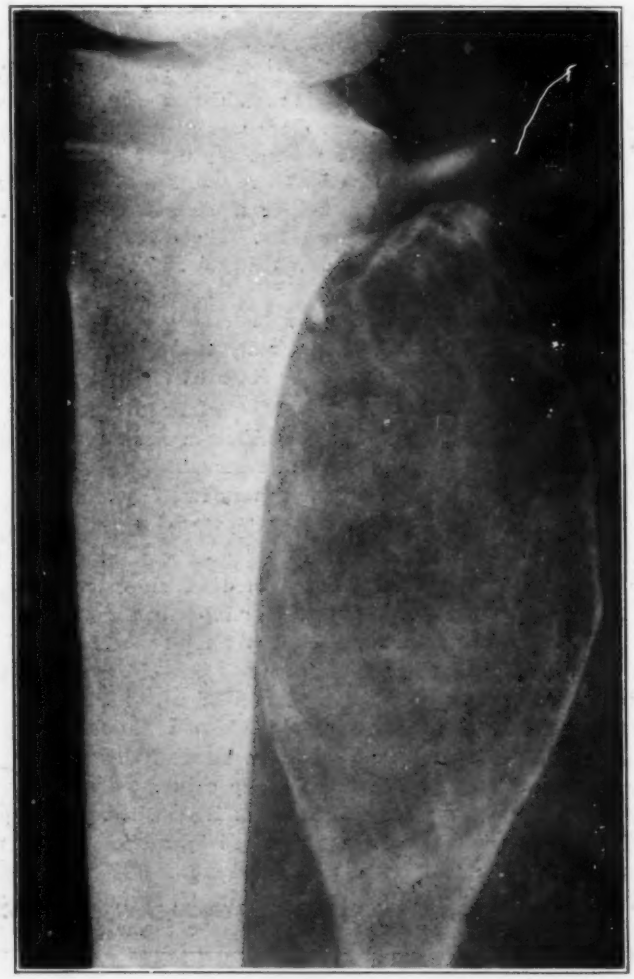

Fig. 31 (Case 8).—Expansion of upper fibula with fine trabeculae across the growth.

of the tumor had extended through the gap (Fig. 33). Other instances of this same phenomenon could be seen elsewhere in the section but the breaks were smaller, and nowhere did the tissue which has broken through extend to the very edge of the tissue removed.

Contrary to the gross impression, the neoplasm contained many small vascular spaces strewn throughout the tumor tissue. The relation of these spaces and

the stroma cells was intimate, as is usual in bone tumors even of doubtful malignancy. The possibility of metastases having already occurred when such a histologic condition is found cannot be easily set aside.

Giant cells were fairly abundant, but not so numerous as is frequently the case in the benign giant cell tumor. Some of these were of the typical epulis type, but many only approximated this type, in that they were smaller, and con-

Fig. 32 (Case 8).—Cut surface of the bisected tumor in the upper third of the fibula. Extension through epiphyseal line above, central cystic areas and thin bone shell may be noted. (For this case history, we are indebted to Dr. William F. Verdi.)

tained only a few nuclei, and the latter were often larger and more vesicular than in the characteristic epulis type giant cell.

The structure of the stroma cells varied in different parts of the tumor. The cells were of the fibroblast type, with well marked fibril formation, shown in

the cytoplasm, indicating a fairly adult type of cell. There were areas, however, in which the cells were of a more embryonic type and more suggestive of malignancy. In such places, as many as three mitoses to a high power field were found. It is of interest that these areas suggestive of malignant appearance were not found in the most peripheral portion of the tumor, where it was destroying the bony shell by pressure and its associated effects.

Fig. 33 (Case 8).—Tumor on right. The bone shell is broken (center) and tumor tissue has extended through into the periosteum.

Throughout the preliminary sections studied, there were found unusual hyaline cytoplasmic areas (Fig. 34), from which fibroblastic stroma cells seemed to radiate. These suggested a focal origin of some sort but constituted a picture we had never encountered before in bone tumors. It suggested the somewhat analogous areas of hyaline stroma in acoustic nerve tumors. A study of sections from additional blocks demonstrates that such areas originate

from foci of bone undergoing absorption. Progressive stages in the development of these rosette-like areas of hyaline material were seen, from those in which the center was marked by a blue-stained, usually circular area of bone (Figs. 35 and 36), in which sometimes viable bone cells were still apparent, to those containing no trace of bone tissue but only the clear glasslike pink-staining hyaline material. Here the cellular association was suggested by clear

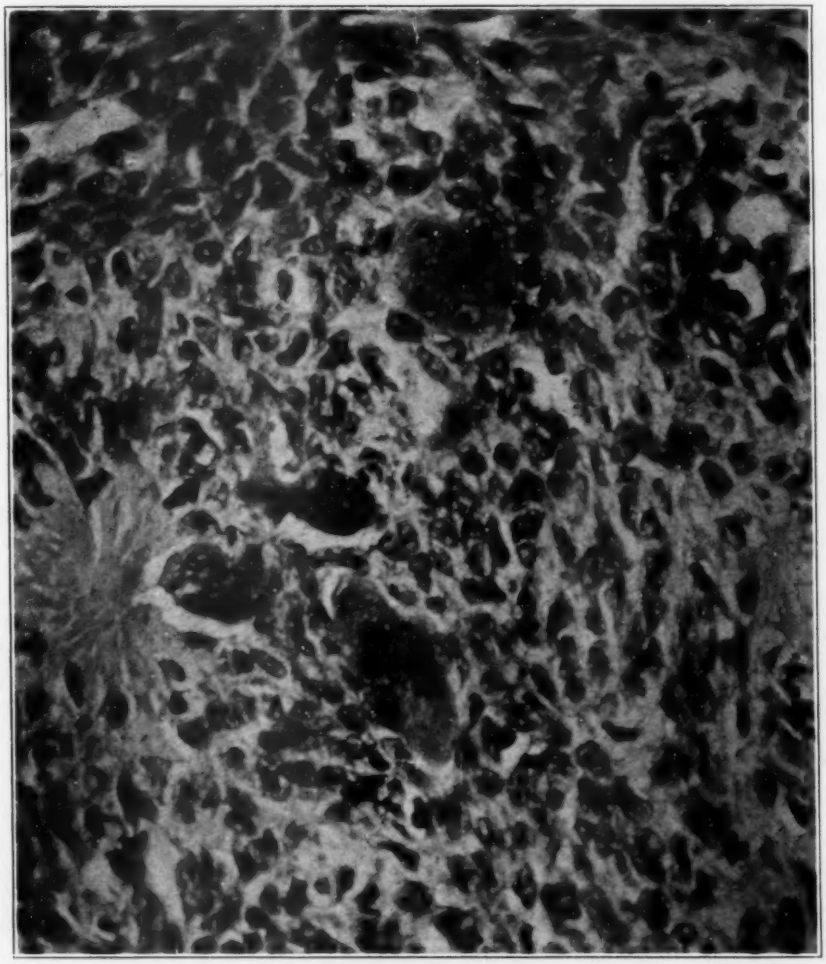

Fig. 34 (Case 8).—Good examples of the giant cells present in this tumor. To the right of the topmost one there is mitosis in one of the stroma cells. A peculiar hyaline area near the left border below the center may be noted.

spaces between radiating segments of the material, as well as by shadows of nuclei occasionally seen in the hyaline portions and viable nuclei adjacent to the periphery of these radiating segments. The nuclei were arranged in line with the long axes of the segments. In intermediate transitory areas, the minute bone fragments contained no demonstrable nuclei and appeared as osteoid

tissue gradually losing its calcium salts. In addition to these small foci of bone, less numerous spicules were seen, undergoing a similar process of absorption. It is of interest that this process appeared to be taking place without the intermediation of osteoclasts.

The final diagnosis was medullary giant cell tumor of an atypical borderline type, probably benign.

Fig. 35 (Case 8).—Remains of bony trabeculae in central portion of tumor, undergoing absorption by connective tissue cells without action of typical osteoclasts.

This case is of interest because of the age incidence and painless course. Bloodgood [10] states that pain has always been a symptom in his group of cases of giant-cell tumor. Giant-cell tumors, also, are not common at such an early age. The roentgen-ray picture shows the

typical extension completely to the end of the bone and the fine trabeculation across the involved area. The gross picture showed a very light creamy brown color, with areas of cysts filled with blood clot. This brings up the question of the gross appearance of giant cell tumors. We have been taught to look for "currant jelly" areas as an index of giant-cell growths. Both this case and Case 3 were atypical in this gross appearance. Stewart [11] reported a case of giant cell tumor in which

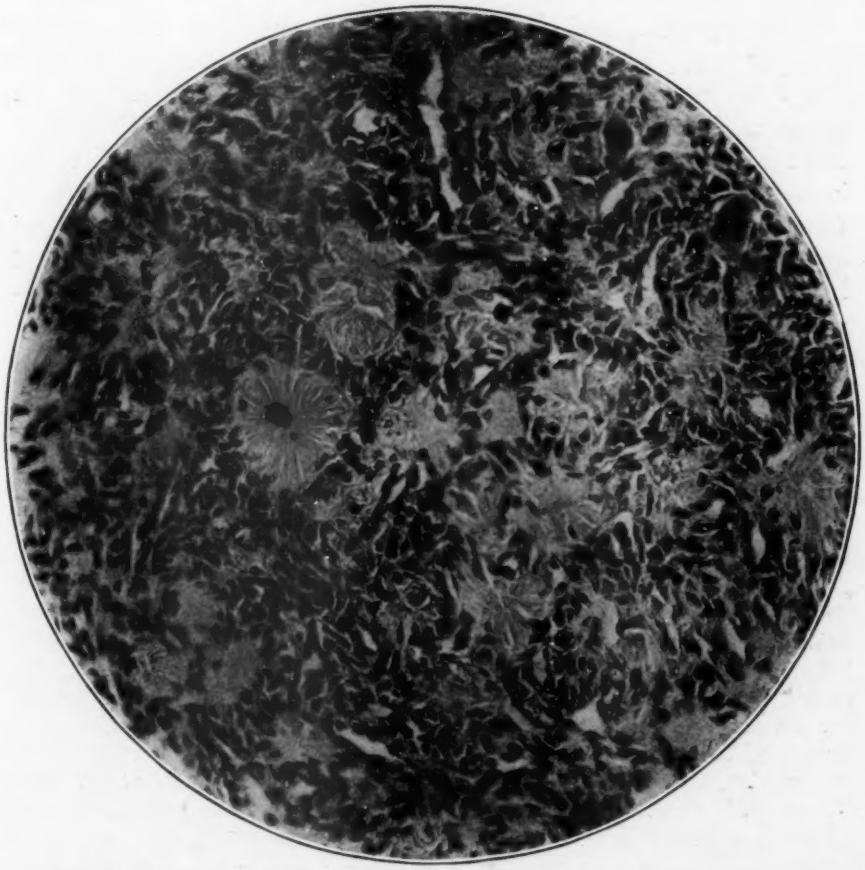

Fig. 36 (Case 8).—Absorption of minute foci of bone nearing completion, leaving roughly circular radiate areas of hyaline tissue. The appearance of this material, with pale vesicular nuclei, peripherally placed, surrounding the minute fragments of bone near the center may be noted.

these areas were white throughout, a character usually given to highly malignant growths.

This neoplasm certainly seems one in which an arbitrary diagnosis for or against malignancy from the microscopic examination alone would

11. Stewart, M. J.: Brit. J. Surg. **10**:322 (Jan.) 1923.

be very uncertain, and in which the gross, roentgen-ray and clinical characters should receive consideration in reaching conclusions. From the standpoint of the gross pathology, the tumor appeared to be a benign one but with evidence of beginning destruction of the bone shell. Microscopically, there were areas suggestive of malignancy, and definite perforation of the bone shell was seen in small areas. In the giant-cell tumor, this latter phenomenon, even when grossly present, has lately been discounted (Bloodgood) as a definite criterion of malignancy.

It hardly seems necessary to emphasize again here what has been so clearly stated by Bloodgood and Ewing, that the character of the stroma cells is the microscopic index of the benignancy or malignancy of the neoplasm, rather than the appearance, number, etc., of the giant cells. Even with this information and some experience, it appears to be impossible to decide definitely one way or the other in all cases. Therefore, it would seem that a definite group of giant-cell tumors of questionable malignancy must be recognized. In these, the clinical features and roentgen-ray findings may bear great weight in the diagnosis. Proper definition of this group can be accomplished only by intensive study of each case, checked by the clinical (ultimate) results.

The peculiar picture presented by minute foci of bone in this case is a unique one for giant-cell tumor.

A frozen section in this instance would cause the pathologist a great deal of worry and the ultimate judgment would probably rest on the surgeon. Resection would seem to have been the logical method of procedure.

CASE 9.—*History.*—H. K., a fireman, aged 36, entered New Haven Hospital, Feb. 23, 1919, with a complaint of soreness over the right elbow. Four weeks before (January, 1919), while pulling a carload of coal, he fell, striking the ground with the right elbow. The elbow was only slightly swollen and painful and did not keep him from working. February 19, four days before admission, the elbow became quite painful, and was opened in the accident room. The patient quit working the next day because of pain on motion of the arm. February 22, the day before admission, the elbow was again opened, and the patient was advised to come to the hospital for operation.

Physical Examination.—The patient was well developed and well nourished. The general condition was normal. The right elbow showed an incised wound 3 cm. in length over the olecranon process. The edges of the wound were gaping, and from the center of this wound there protruded a small rounded mass, 1 cm. in diameter, directly over the tip of the olecranon process. The tumor mass was attached to the bone by a firm pedicle. There was considerable induration about the wound. A discharge not purulent, but serosanguinous was present. No bone area was exposed. There was very little tenderness. Movements of the elbow joint were normal and caused no pain. There was no sensory disturbance of the forearm. The wrist and fingers moved normally. No enlargement of the glands in the right axilla was noted.

Operation (February 24).—Dr. Deming excised the tumor of the right elbow. An elliptic incision was made well around the old wound and the superficial tissue and a portion of the olecranon were removed, together with the tumor. The base of the tumor was firmly attached to the bone. This portion was chiseled so that the fragment of bone 2 cm. in length was removed (Fig. 37).

March 8: The wound was healing. There was no discharge and no induration. Movements of the elbow were normal. The patient was discharged, to return to the hospital for dressings.

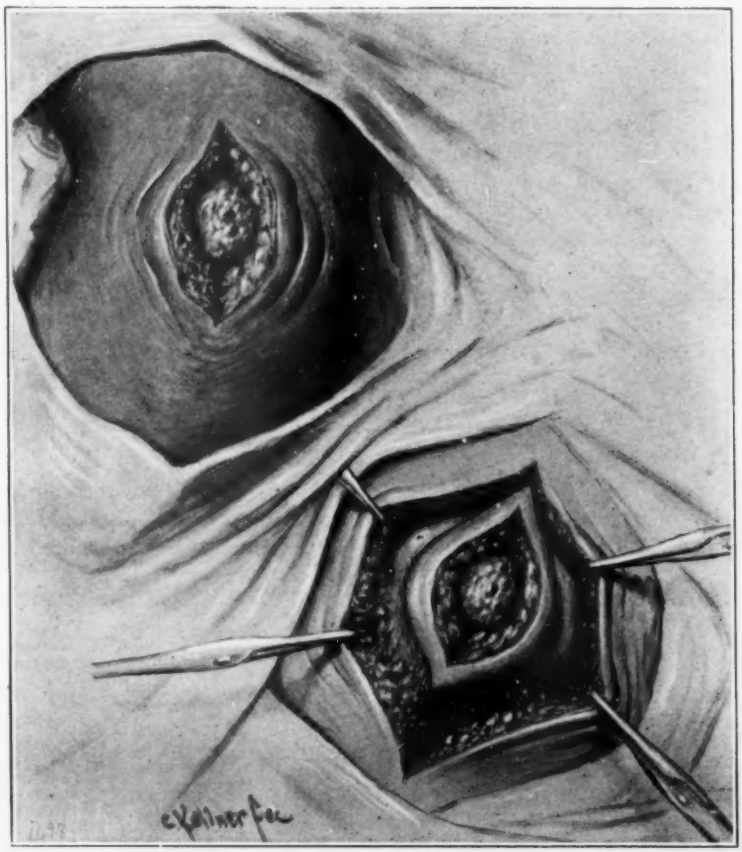

Fig. 37 (Case 9).—Above: Appearance of wound when patient was admitted to hospital. The protruding tumor-like mass is evident. Below: Appearance at operation, showing the amount of skin margin in removal of the mass.

Roentgen-ray examination was negative, except for a small exostosis.

Urine examination was also negative. Blood examination was not made. The patient was lost sight of.

Pathologic Examination.—Gross pathology: The excised mass (preserved in oil) consisted of an underlying fragment of bone 3 by 1.5 cm. in diameter, superimposed on which was a mass of tissue now in its shrunken condition 1.5 cm. in diameter. This was quite firm and fibrous in texture and constituted

the supposed tumor. Just beneath it, a longitudinal section of the bone showed the questionable exostosis which appeared in the roentgenogram. The specimen was excised with a wide margin. There was no definite gross indication of malignancy. One could judge little of the original color from the present color. Blocks were taken through the center of the questionable mass, including underlying bone for microscopic examination.

Microscopic examination: At the point noted as an exostosis in the gross description, new bone formation was seen to be progressing, with corresponding activity of osteoblasts, in one of which a mitosis was seen. The periosteum was somewhat thickened, especially at this point. There was some mononuclear infiltration and an occasional polymorphonuclear could be seen. Extending outward from the periosteum throughout the mass of suspected tumor tissue, one found only a chronic rather vascular granulation tissue with no evidence of a neoplasm or specific granuloma (tuberculosis or syphilis). The bone underlying the periosteum was normal.

Near the periosteum in one area was a cleft in the section filled with red blood cells and fibrin, with beginning organizatin. Whether or not this was the remains of the traumatized bursa, it is impossible to say definitely but it was rather suggestive. No giant cells of the epulis type were found, but two or three smaller giant cells of the foreign body type were found in the inflammatory tissue; which is most unusual. These were in the vicinity of what appeared to be lymph spaces.

On the surface of the granulation tissue, there was an exudate consisting of red blood cells, serum, fibrin and relatively few polymorphonuclears and lymphocytes. Foreign body substances were searched for, but no definite ones were found.

The final diagnosis was chronic inflammatory tissue tumor (granuloma), associated with chronic traumatic periostitis and probably bursitis of traumatic origin. There was no definite evidence of foreign body implantation.

This man showed a growth on the olecranon process. It was of short duration and apparently accompanied by infection. From our study of the roentgenogram, which shows only a slight periosteal reaction, and the microscopic picture, which gives no evidence of malignancy, we would conclude that this case should be classed as a periostitis and not a true bone tumor. The ultimate outcome is not known.

The specimen is interesting as illustrating the difficulty which may be experienced in distinguishing granulation tissue from tumor tissue even in the microscopic sections. This is a truism which even experienced clinicians have freely admitted. It emphasizes the importance of a clinical check up (by means of ultimate results) on pathologic diagnoses of tissue removed at operation. With regard to this difficulty in the case under consideration, it may be noted that certain areas in the mass of granulation tissue consisted largely of younger fibroblasts simulating true myxomatous tissue. Such cells, however, showed more tendency to fibril formation than prevails in true myxoma.

CASE 10.—*History.*—J. S., a man, aged 63, entered New Haven Hospital, Nov. 13, 1916, complaining of a sore, swollen toe. He had had pleurisy twenty

years previously, and an operation for swelling in the right groin ten years previously. The family history was unimportant.

Three years before (1913), the patient noticed that the right great toe was red. There was slight soreness. The toe gradually grew larger. During the last year, the toe had become painful and for the last six months he had been unable to sleep at night because of paroxysms of throbbing pain. Walking aggravated the pain. Ten years before (1906), the same toe was broken, but the patient had no medical attention.

Physical Examination.—The patient, a well developed and fairly well nourished old man, lay in bed with the right leg flexed on the thigh. His teeth were badly worn and many were capped. The thorax was asymmetrical. The

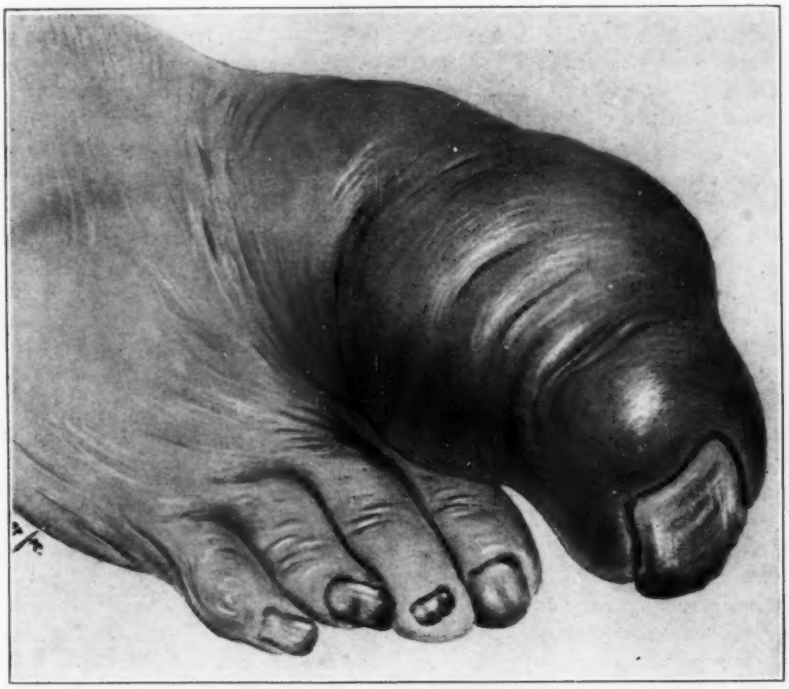

Fig. 38 (Case 10).—Appearance of toe at time of patient's admission to hospital.

right chondrocostal junction of the sixth and seventh ribs seemed much enlarged and thickened. There was a short systolic murmur at the heart apex transmitted to the neck. The radials, brachials, and temporals were thickened and tortuous. In the right inguinal and femoral regions, there were two operative scars, between which there was a pulsating expansile tumor, 4 by 6 cm. in diameter. There was no thrill or bruit heard. Underneath the artery, in the neighborhood of the perineum was a definite tumor the size of an egg. It felt like a bony tumor originating from the horizontal ramus of the pubis. The right hip was ankylosed. There was some edema of the right leg. The right great toe was much enlarged and lobulated, the skin was reddened and

fluctuation was present on the top. The swelling reached the metatarsophalangeal joint. There was local heat present. The rest of the foot appeared normal (Fig. 38). There was a slight swelling of the left knee due to an old dislocation.

November 15: Aspiration into the fluctuating area showed straw-colored mucoid material so thick that only a very little could be obtained (about 4 drops) even with a No. 18 needle. The vital signs were normal. The urine was clear, with a slight trace of albumin and no microscopic elements. Bence-Jones tests were not reported. Blood examination revealed: white blood cells, 9,200; polymorphonuclears, 83 per cent.; large mononuclears, 1 per cent.; lymphocytes, 16 per cent.; hemoglobin, 80 per cent. The Wassermann test of the blood was negative.

Operation (November, 21).—Dr. Flint performed a partial amputation of the right foot. The mass was disarticulated at the scaphocuneiform joint and the first cuneiform bone was removed with the mass.

The postoperative course was satisfactory and, December 3, the patient was discharged from the hospital to the care of a local physician.

Second Admission (Jan. 22, 1918).—The swelling on the dorsum of the foot recurred about three months after operation and slowly became larger. It was painful when the patient walked but at no other time.

The patient was undernourished, and had atrophic skin. The chest was asymmetrical owing to enlargement of the costo-chondral articulation of the seventh and tenth rib. The percussion note was hyperresonant except opposite the second intercostal space near the sternal line, where the note was dull. Posteriorly, no area of dulness was found. Breath sounds were everywhere normal. An occasional moist râle was heard. The abdomen was asymmetrical, owing to the fulness corresponding to the place on the rib. The abdomen was sensitive and palpation was very unsatisfactory, but the impression was that there was an enlarged lobe of the liver. The percussion note was dull. The upper extremities were normal. There was a diffuse swelling over the right external ring in the inguinal region. Extensive impulse was felt through the dilated ring on coughing. There were two surgical incisions over the right groin, the longer being about 8 inches from the anterior-superior spine, parallel to Poupart's ligament and down to the midthigh. Beneath this scar was a large mass aparently attached to the femur. Just medial to this was a swelling extending from Poupart's ligament down the leg nearly to the knee. This was freely movable and apparently a part of the adductor muscle. The hip was ankylosed. The foot showed an amputation at the tarsal-phalangeal joint. The scar was well healed. Just above this was a hard fusiform enlargement which involved the entire dorsum of the foot and obliterated the internal malleolus. It was very tender and the skin was not movable over it. The right leg was normal except for marked cavus.

Roentgen-Ray Examination (January 27).—The first metatarsal and phalanges were absent. There was atrophy of all of the bones of the foot, most marked in the tarsal bones and terminal head of the metatarsal. The cuboid showed marked periosteal reaction and some osteitis. There was some increased bony tissue. The articular spaces were clearly outlined.

January 31: There was evidence of bony destruction of the great trochanter of the femur. The destruction, however, was peripheral. The pubic bones near the symphysis showed a rather marked halisteresis. There appeared to be no

proliferation or other destruction of bones. The sixth, and especially the seventh and eighth ribs on the right showed a definite destructive process involving the cartilage and considerable of the terminal costal portion.

February 11: The patient received daily increasing doses of Coley's serum up to 4½ minims. The mass over the right groin previously fixed became movable. The other tumor masses remained about the same.

February 23: The patient refused daily increased doses of serum. The present dose was 9 minims. The tumor over the ribs showed no change, nor did the groin. The foot remained very tender. The measurements were unsatisfactory. The circumference of the foot anterior to both maleoli and around the arch of the foot was 29 cm. The skin was now movable and the outlines of a nodular mass involving the metatarsal bone could be made out. Previously, the tumor could not be outlined.

March 8: The patient received injections in the buttocks and right calf of leg, up to 25 minims, with no reaction. The tumor, which at first appeared to grow smaller, was now increased in size and the pain became more intense.

March 28: The patient was able to walk about the ward. No change was seen in the tumor masses. The patient was allowed to go home until arrangements were made to send him to New York Memorial Hospital. He was discharged, unimproved.

Vital signs had been normal throughout his stay in the hospital. The urine examination was negative. The white blood cells numbered 9,400. The red blood cells were normal in appearance. Hemoglobin was 80 per cent.

Third Admission (August 5).—No history in the interval was given except that the pain in the foot became continual and increased in severity. The patient could not sleep well on this account, especially in the last six weeks.

The abdominal muscles were held rigid, but there was no tenderness in the abdomen. Liver dulness extended 1½ inches (3.7 cm.) below the costal margin in the midclavicular line on the right.

On the right foot, covering the dorsum and apparently connected with the bones of the tarsus, was a rounded tumor about 8 cm. in diameter. The skin over the tumor was tense and red, but apparently not adherent. The tumor was tender to pressure and caused the patient much pain. In the right inguinal region, there was a nodule 2 by 4 cm. in diameter. It was hard, not tender, and fairly freely movable.

Second Operation (August 8).—Dr. Whittemore performed circular amputation of the right leg at the junction of the lower and middle thirds.

August 25: The stump was very tender to pressure. There was no swelling. A small unhealed area remained in the center. There was no reddening. The patient was discharged from the hospital with instructions to return for dressing.

The urine showed a slight trace of albumin and a few casts. Otherwise, it was negative.

Sept. 12, 1919: The patient died from malignancy.

Pathologic Examination.—Grossly, the specimen consisted of a half section of a tumor mass about as large as a medium sized lemon, although less regular in outline. It involved the first phalanx of the great toe and had destroyed this together with the proximal portion of the terminal phalanx, which showed an irregular erosion.

The specimen had apparently shrunken considerably, the skin lying in wrinkled folds, although it seemed to have been under considerable tension from the underlying tumor at the time of amputation. The exposed cut

surface of the tumor was soft and irregular, resembling an old sea sponge. On close inspection, the softer portions of the tumor seemed to have fallen out. On making a fresh cut, a smooth, soft, but elastic surface with large hemorrhagic markings was seen. The tumor seemed encapsulated toward the skin and at its upper extension, but the destruction of the phalanges gave sufficient evidence of its invasive character. No cartilage was recognized.

The gross diagnosis was sarcoma of the proximal phalanx of the great toe.

Microscopic examination: Sections from five different blocks, all of them containing tumor tissue were available for study. Of these, only two showed definite malignancy, one was doubtful and two were negative, although they were selected directly from the tumor.

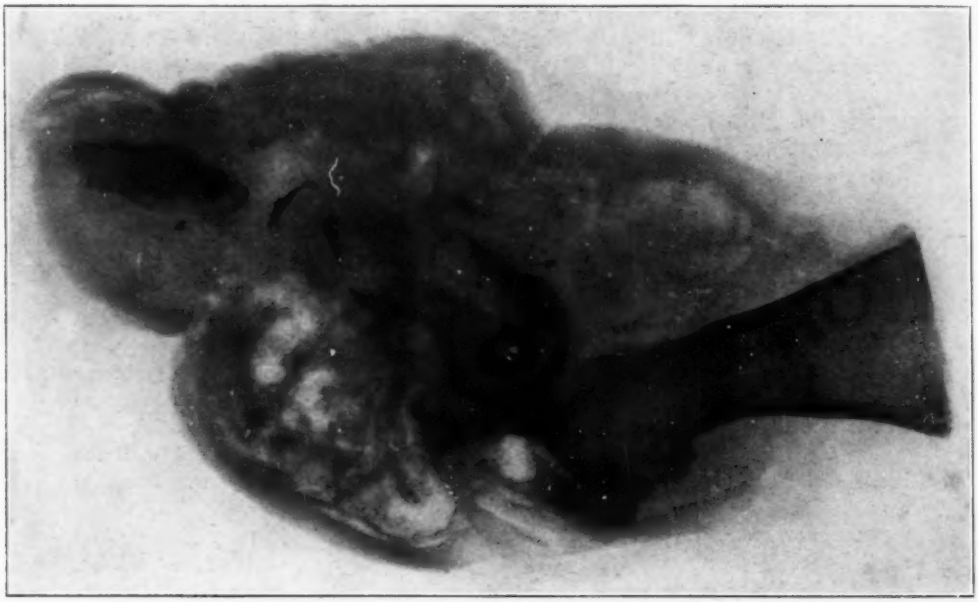

Fig. 39 (Case 10).—Roentgen-ray appearance of growth shown in Figure 38. There is marked destruction of phalanges and invasion of soft tissues.

The neoplasm was not an infiltrative one, so far as can be judged from these sections alone, but apparently was circumscribed with definite encapsulation. The periphery was rounded and composed of lobules, which in turn often showed at their periphery a narrow zone of cartilage. This abruptly shaded off into myxomatous tissue toward the centers of the lobules. At times, the entire lobule contained only myxomatous tissue, which for the most part was associated with an abundant ground substance, or matrix, possibly mucinous in character, staining a light blue and apparently a result of secretory or degenerative processes of the cells (Fig. 40). In the sections containing no definite malignant tissue, this material was very prominent and appeared to have played a rôle in the extensive areas of necrosis present. Some of these were 1 cm. or more in diameter. In such areas, no viable cells were to be seen, but unstained shadows of cells were scattered throughout.

When there was definite sarcoma, it occurred frequently in areas apparently in transition from myxomatous zones. In such places, the spindle-cell type of sarcoma prevailed, with occasional giant cells of the malignant type.

The diagnosis was myxochondrosarcoma of the proximal phalanx of great toe.

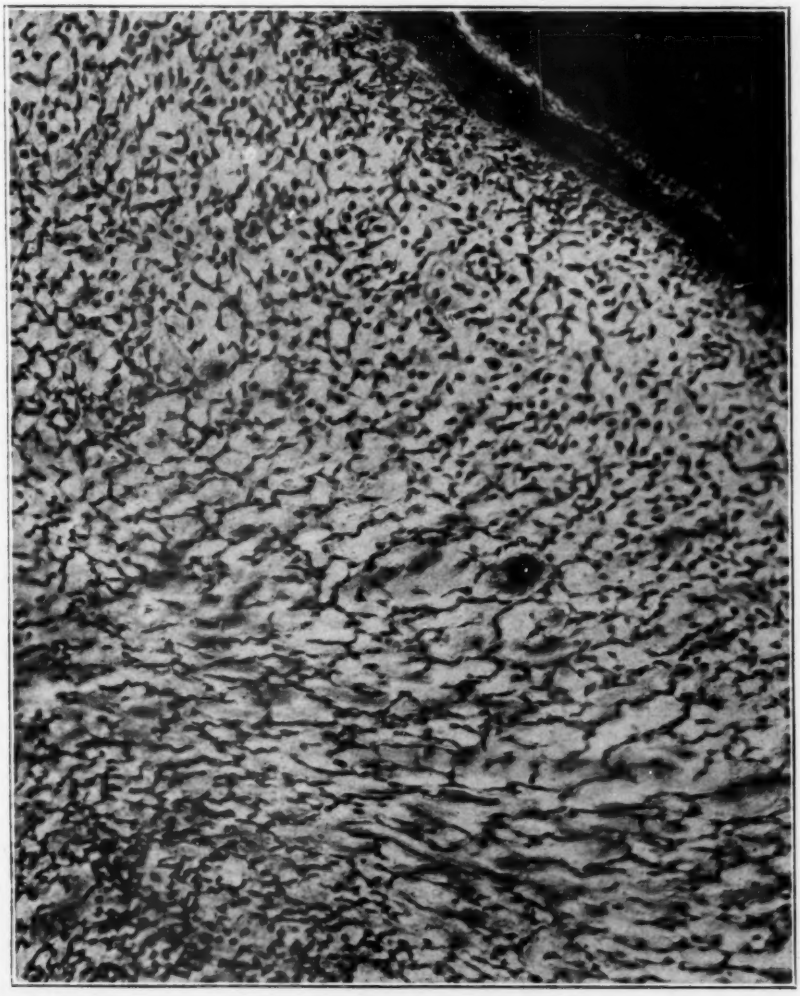

Fig. 40 (Case 10).—Myxomatous tissue, with no areas of definite sarcoma.

The evidence of malignancy in this case consisted in the painful swelling and deformity of the toe; the age incidence; the marked bone destruction and invasion of the soft parts, well shown by the roentgen ray (Fig. 39), and the pathologic studies, which demonstrated areas of myxoma, sarcoma, etc. Were one to attempt a diagnosis from frozen section alone, there is the possibility that an area of pure myxoma

might have been selected. In fact, only two blocks of five studied showed signs of definite malignancy. This is a source of error that must be kept in mind when the decision rests on the microscopic section. The combined gross and microscopic appearances and the clinical behavior must be taken into consideration in every instance and the surgeon's judgment must rest on an evaluation of all the factors, together with his knowledge of the outcome in similar instances as reported by his colleagues. The question naturally arises as to the operative procedure chosen for this case. If the surgeon had been more radical, attempting a Syme's amputation or even a lower third of the leg, would recurrence have taken place?

This neoplasm is of a type which is known to recur with great regularity and ultimately to kill by metastasis. It seems to constitute a group, the nature of which is recognized late, after one or more operations. A more radical procedure based upon a diagnosis made at the first exploratory incision might lead to better results. These tumors are usually quite soft, and it might be well if only myxomatous material was suspected at operation, to adopt Bloodgood's [12] idea of their malignancy.

The occurrence of a destructive process in the femur and ribs is hard to explain on the basis of metastases unless dissemination was very widespread, as the sarcomas of bone use the blood stream as a pathway. The marked improvement under Coley's toxins indicates that this form of treatment might have been a very valuable asset early in the disease.

SUMMARY

From our study of this group of cases, we are impressed with the difficulties which confront the average surgeon in arriving at the proper diagnosis and deciding on the proper treatment in any group of bone tumors. Certain growths are well defined and conform to type; but there are so many exceptions to the rule that each case must be most carefully studied and weighed before action is taken. Were we to trust to the roentgen-ray picture for our diagnosis, we would be deceived in a number of instances; were we to depend on microscopic section alone, especially at the operating table itself, we would be often misled. And the clinical behavior may at times be confusing, although in general it is a most valuable index. By considering all methods, weighing them carefully, our decision must be arrived at, and then in many cases the only true test we have is that of time. The surgeon who will perhaps make the fewest mistakes will combine a knowledge of the gross and microscopic appearances and clinical behavior of the commoner types of bone tumor. We agree with Ewing [7]

12. Bloodgood, J. C.: Ann. Surg. **77**:106 (Jan.) 1923.

that "the gross anatomy of the lesion is often a safer guide than the variable and uncertain structure of a small piece of tissue." This experience can be obtained only through the collection and study of a group of these neoplasms, such as is planned by the Registry for Bone Sarcomas. The Registry would confer a great boon on surgeons if a series of accurately drawn and colored plates of the various types of growth were published and placed on sale so that operators could know what "the currant jelly" of the giant cell, etc., actually looks like in the gross. Many such colored plates would undoubtedly be published in case reports were it not for the expense, and contributions of this kind to the Registry could no doubt be obtained.

It would be a fairer test of the value of the Registry, if the diagnosis could be given from the available information that the clinician has; namely, clinical history, roentgen-ray findings and pathology. When the end-result is likewise known, judgment is not in some cases so difficult. We feel also that through the Registry we may get a point of view which may not represent the whole truth on the subject as there are undoubtedly many men who have amputated limbs for bone tumors and for one reason or other, medicolegal, for example, do not wish too close an investigation as to the nature of the tumor removed. In this way, many of the real cases of cure in amputation for osteogenic sarcoma may be hidden under a bushel of failures.

Finally, when the tumor has had a very rapid growth and has progressed extensively when first seen, more conservative treatment with radiotherapy and other measures, at least until we get more information, would seem to meet the situation better than the radical amputations of the past.

NOTES ON FIVE CASES OF PAGET'S DEFORMING OSTEOMYELITIS

WITH DESCRIPTION OF THE SPECIMEN OF A FEMUR FROM A SIXTH

LEONARD W. ELY, M.D.

SAN FRANCISCO

Three cases of Paget's deforming osteomyelitis have been observed at the Stanford Clinic during the past few years. To these I have added one private case. Data in the possession of several of my San Francisco colleagues indicate that the disease is not so rare as is generally thought.

REPORT OF CASES

CASE 1.—*History.*—A man, a hardwood finisher, aged 57, was admitted to the neurologic clinic, Dec. 18, 1912, with a complaint of noises in the ears and in the right side of the head. His mother died of cancer. He had been married thirty-three years, and his wife and four children were alive and well. The wife had miscarried four or five times. No history of syphilis was elicited, but alcohol and tobacco had been used excessively.

The onset of the present condition was insidious, about seven years previously, with "wrecking of the system." The patient was at that time 5 feet 4 inches (1.6 meters) tall. Pain developed in the back, and the back began to bend, and the arms and legs to bow. Five years previously the buzzing noises began in the right ear and right side of the head. The pain in the back slowly increased, until two years previously it became so bad that the patient was forced to give up work.

Physical Examination.—The patient was very short, measuring but 4 feet and 9¼ inches (1.45 meters). He had a posterior spinal curvature, and the legs and forearms were bowed, the right forearm more than the left. The distance from the tip of the olecranon to the styloid of the ulna, was, left, 25.5 cm.; right, 26.5 cm. The neck was extremely short and thick, and the head was large. The parietal diameter was especially great, and the upper part of the head was disproportionally large.

There was contact hearing only. The eye fields were concentrically contracted; vision in both was 20/30, and the fundi were normal. The teeth were much worn; some were loose, and pyorrhea was present. The tonsils were atrophic. The chest was barrel shaped; the vertebral column was apparently shortened, and the ribs almost touched the ilia. The clavicles were thickened, and the costal margins flared markedly. The lungs showed signs of chronic emphysema. The heart was enlarged to the left, and a systolic murmur was heard at the apex, imperfectly transmitted. The peripheral arteries were markedly sclerotic. The abdomen was protuberant. Some general glandular enlargement was present. The blood pressure, systolic, was 155 mm. The urine was free from albumin and casts.

The red blood corpuscles numbered 4,650,000; the white, 8,000. Hemoglobin was 84 per cent. The spinal fluid analysis and Wassermann tests (blood and spinal fluid) were negative.

Treatment.—After a short stay in the hospital, the patient resumed his visits to the neurologic clinic. He received thyroid tablets and potassium bromid, and was treated with the galvanic and static currents. He improved in some respects for a while, but his stature slowly decreased.

Second Admission (April 12, 1916).—His height now was only 4 feet and 6 inches (1.37 meters). He gave a history of an attack of diarrhea about two

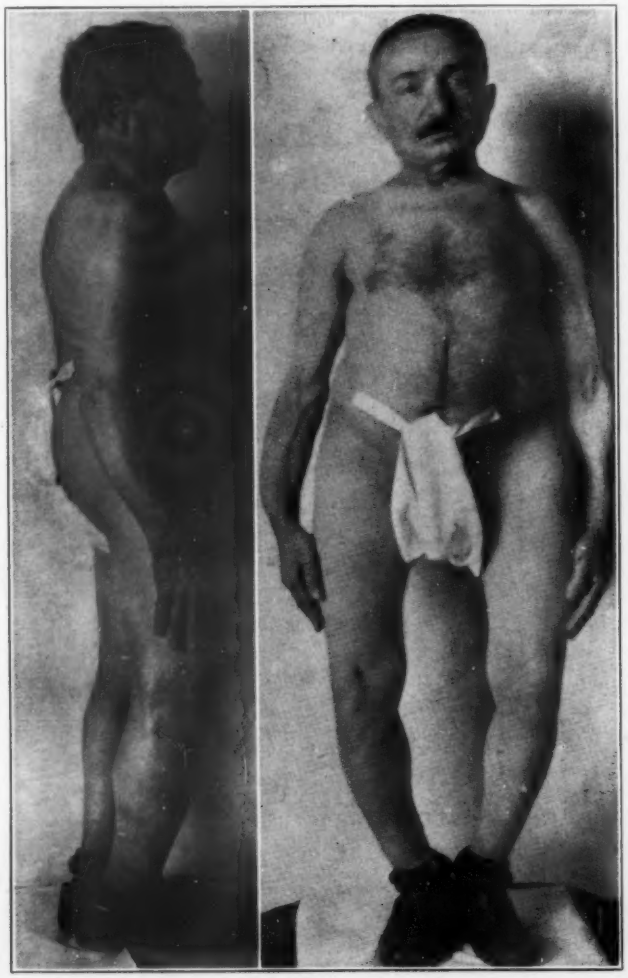

Fig. 1 (Case 1).—Front and side views.

months before admission, with chills and some fever, lasting about three weeks. After this, nycturia and smoky urine developed. Since January, 1916, the urine had on different occasions shown albumin, and hyaline and granular casts, a few white blood corpuscles, and many red blood corpuscles, the last becoming more numerous. He was put on a chronic nephritis diet, and left the hospital after two weeks. For the subsequent course of the disease, I am indebted to Dr. Walter Schaller, into whose care he passed.

The Course.—The symptoms of Paget's disease slowly increased, so that locomotion became impaired, and the patient was forced to resort to the use of canes, and then crutches. The gait became waddling, and he suffered from pain in the thighs.

Early in July, 1918, the urine showed bile pigment, and then the sclerae and the skin became jaundiced, and the stools became clay colored, with an offensive odor. Somewhat later, the patient began to complain of slight distress in the upper abdomen, and a feeling of pressure. Examination revealed an enlarged liver, about 3 inches (7.5 cm.) below the costal margin and quite tender. Chills and fever soon became pronounced, the chills finally occurring twice a day. The patient gradually grew worse, finally going into a definite coma. He died, Sept. 6, 1918.

Necropsy (Dr. Knapp.).—The body was that of a dwarfed, gray-haired man, about 55 years old, emaciatetd and jaundiced, and showing marked skeletal deformity. The spine was bent forward on the pelvis, and was kyphotic and scoliotic. The legs were much bowed out; the chest was very prominent laterally, and the lower ribs were spread widely apart. The head was very large, with small, pinched features. The temporal, frontal and parietal regions were bulging, and the occipital region was flattened. There was no definite change in the bones of the face, but the features appeared small in comparison with the skull. The clavicles were large and curved. The radii were bowed, the right much more than the left. The left clavicle was removed for histologic examination. The teeth were very poor, only a few stumps remaining.

There was a very small amount of subcutaneous dark fat. The muscles were dry and pale. There was marked calcification of the costal cartilages. The diaphragm was at the fourth rib on both sides. The colon was distended with gas. There was about 200 c.c. of bile-stained fluid in the abdomen. The omentum was short, and contained little fat. The liver was about three finger-breadths below the costal margin. The gallbladder was completely covered over with dense adhesions, in which the duodenum and the hepatic flexure of the colon were firmly massed together. In this mass, in about the position of the common duct, there was a large calculus, about 5 by 1.5 cm. in diameter. There was much fecal matter surrounding it, and it appeared to be partly within the duodenum. On dissection of the adhesions from the liver, a large amount of greenish, purulent material escaped from its under surface, apparently from the bile duct.

There was nothing noticeable in the region of the thymus. A small amount of fluid was present in the pericardium. The heart was of normal size. There was a marked fibrous thickening of the pericardium over the right auricle. The chambers and the valves of the heart were normal, but the wall of the left ventricle seemed somewhat thicker than normal. The aorta was normal, except for a small yellow patch near the tricuspid valves. The large arteries seemed remarkably elastic for the apparent age of the subject.

The thyroid was small, but otherwise not remarkable. The spleen was slightly enlarged, and the splenic vein was quite prominent. The capsule was irregularly thickened, and in one thickened area considerably calcified. The cut surface showed normal but rather indistinct markings.

The right kidney was of normal size. The capsule was adherent, and the surface was finely granular, with irregular depressed scars in the cortex. The cut surface showed the cortex and pyramids very pale and cloudy. The pelvis and ureter were normal. The suprarenal showed postmortem softening. The condition of the left kidney was the same as that of the right. The prostate was normal.

The rectum, sigmoid, colon, appendix, ileum and pancreas appeared normal. The liver was considerably enlarged, and felt boggy. Its cut surface showed innumerable small, and numerous quite large, abscesses, filled with greenish, necrotic material. In the more normal parts, the liver lobules were surrounded by a distinct greenish discoloration, as of stagnant bile.

The diagnosis was: Paget's deforming osteomyelitis; chronic cholelithiasis with obstructive jaundice; multiple liver abscesses; abdominal, pleural and peri-

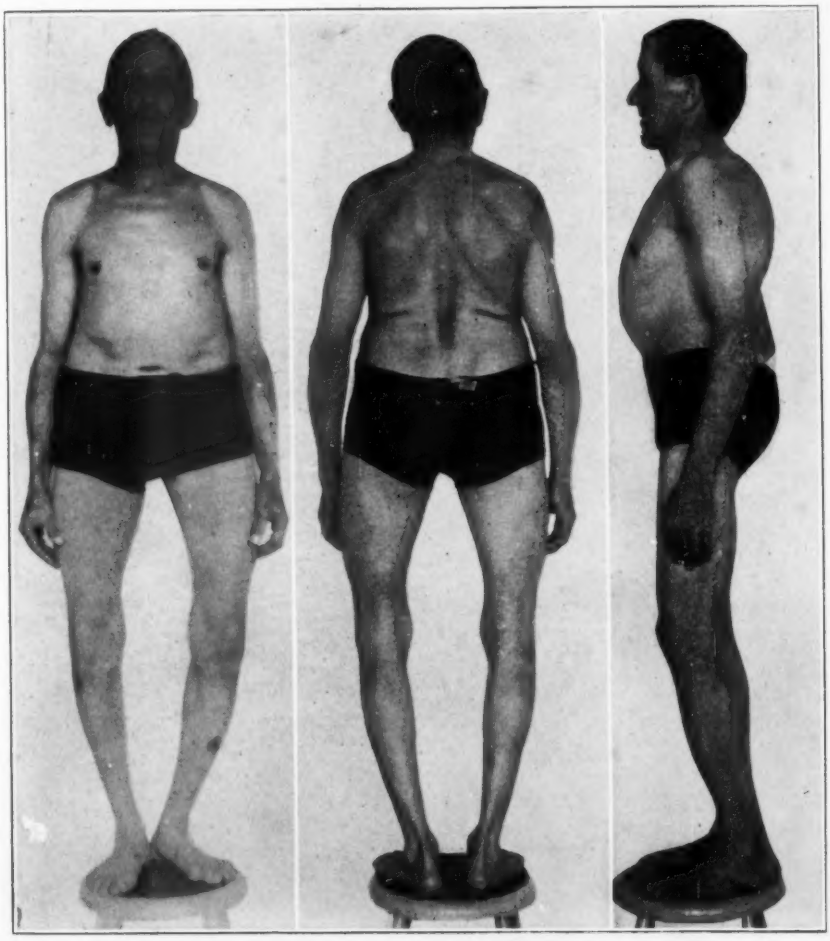

Fig. 2 (Case 2).—Front, back and lateral views.

cardial effusion; old perisplenitis; old pleurisy; chronic oral sepsis; pachyarteriosclerotic kidney, with cloudy swelling; beginning atheroma of the aorta; general emaciation, and secondary anemia.

Case 2.—A. B., an English seaman, aged 47, registered at the Stanford Clinic, February 28, 1922, gave the following history: His mother was alive and well. His father died of cancer at about the age of 64. One brother was alive and well, three or four brothers died in infancy. With the exception of

malaria about thirty years before, and a gonorrheal infection fifteen or twenty years before, the patient has been in good health. No history of syphilis was elicited.

In 1909, the patient was seized with a sudden pain in the back. He was in the hospital for ten days, and had had more or less pain in the back ever since. There had been pain in the legs for years, especially in the shins. In 1915, he

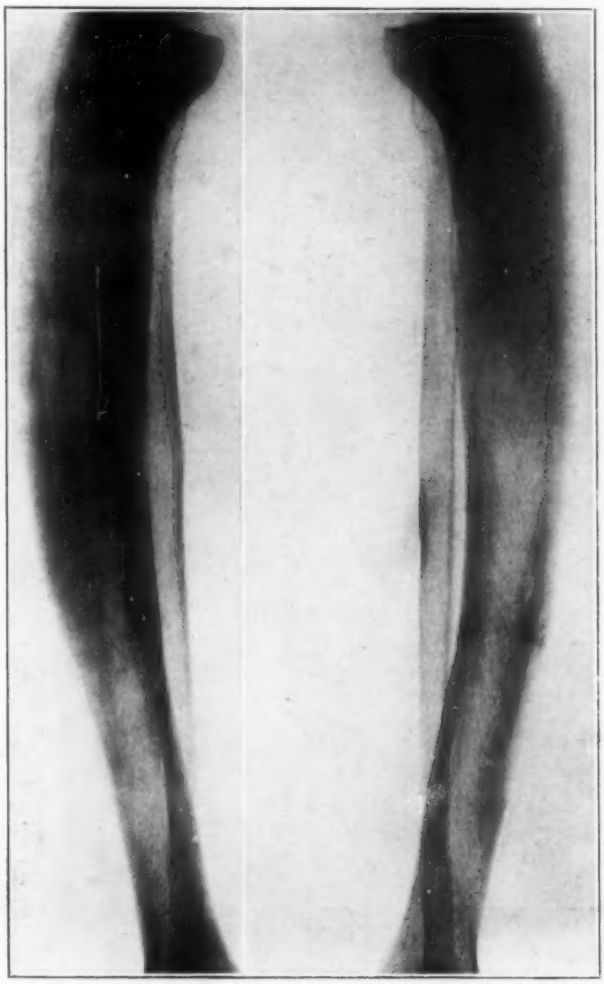

Fig. 3 (Case 2).—Appearance of leg bones.

had an attack of "rheumatism" all over the body, lasting about eight months. For the past year, he had had pain in the feet and ankles. Six months previously, he had another attack of "rheumatism," which lasted for about one month. For the past three weeks, he had had severe pain in the head, and two weeks previously the pain spread all over the body, and had grown worse. It was usually dull, but occasionally became sharp, and was so severe now that it kept the patient from work. The knees became swollen, and "the bones were

getting out of shape." He had had some trouble with his teeth, and considerable postnasal catarrh, but no sore throat. He had been very deaf since the attack of "rheumatism" in 1915.

Physical Examination.—The patient was markedly bow-legged, and the bowing seemed to involve both the tibiae and the femora. The tibiae were bowed anteriorly also. The trunk was very short in comparison to the extremities, and seemed to have sunk down into the pelvis. The anteroposterior diameter of the thorax was increased. The back was markedly rounded in the

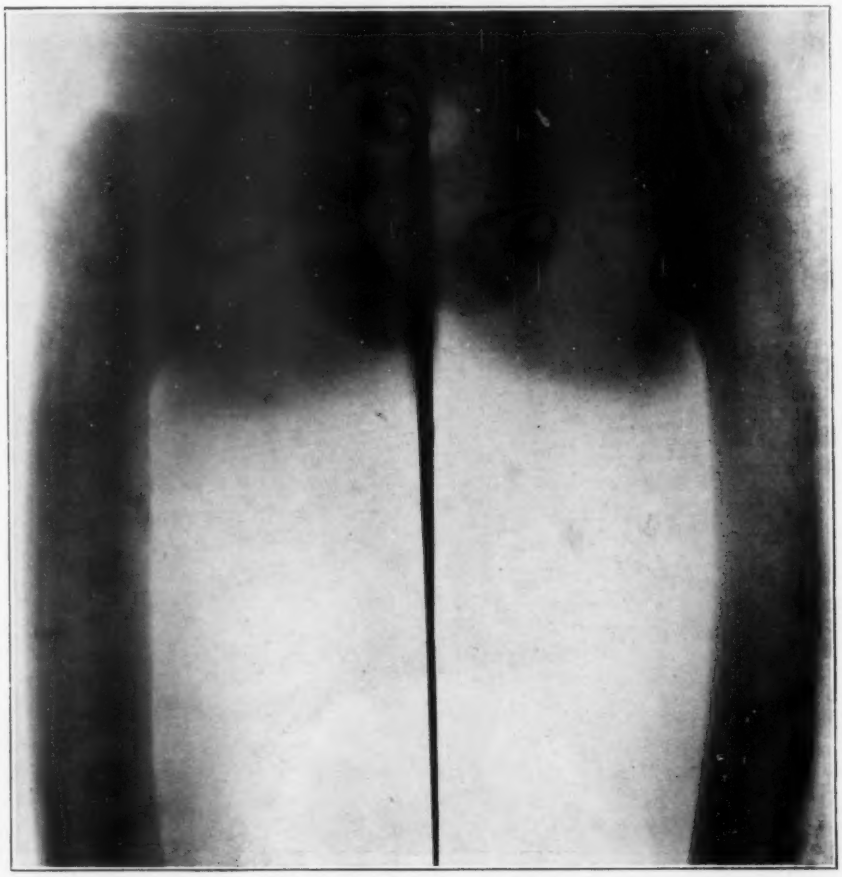

Fig. 4 (Case 2).—Appearance of femora.

thoracic region; the shoulders were narrow, and the clavicles were prominent. The right clavicle appeared thicker than the left. The neck was short and thick; the orbits were large, and the eyes deep set. The skull was asymmetrical and pear shaped, with various bosses. The upper extremities appeared disproportionally long. The postcervical lymph nodes were palpable, but the epitrochlears were not. No limitation of motion in the joints was demonstrable except in the spine. The patient had lost several teeth, and the condition of several of those remaining suggested infection.

The temporal arteries were enlarged and tortuous. Moderate arcus senilis was present. The lungs were hyperresonant but were otherwise negative. The heart was negative. The blood pressure was 110 systolic, 70 diastolic, when the patient was in a recumbent position.

The urine showed a faint trace of albumin, a few hyaline casts and a few fine and coarse mucous shreds. The specific gravity was 1.024. The Wassermann test was negative.

The roentgen ray examination revealed abscesses at the roots of several teeth, and changes typical of Paget's deforming osteomyelitis in the tibiae,

Fig. 5 (Case 3).—Appearance of proximal end of femur. The second type changes in the hip are evident.

calvarium, femora, clavicles, spine and pelvis. In addition, the vertebrae showed characteristic spurring of the second great type of chronic arthritis.

The affected teeth were extracted, and the patient was put on potassium iodid, but he sailed for Australia shortly afterward, and was not seen again.

Case 3.—*History.*—M. E. H., a widow, aged 61, presented a case which was peculiar in its rather acute onset, and its sharp localization. The patient's father dropped dead at 81, apparently of some cardiac trouble. Her mother died at 80, two or three months after being injured in a street car accident. The

patient was one of five children, two of whom died in adult life, presumably of late cerebrospinal syphilis. The other three have always been in good health.

At 60 years of age, the patient had an attack of pain in the right knee, lasting for two months. Six months later, she had an attack of lumbago, which lasted for about one month. She had had much trouble with the teeth, and many years ago had the teeth removed from the upper jaw. Six days previously, she was suddenly seized at night with a severe pain in the back, running down the right thigh, along the sciatic nerve. When I first saw her, she was lying on the left side, and in so much pain that a physical examination was impossible, but it was noted that the Kernig manipulation on the left caused pain in the right sacro-iliac region. She was taken to Stanford Hospital in an ambulance.

Examination.—Roentgenograms revealed a normal lumbar spine, slight changes of the second great type of arthritis in the knee, and changes peculiar to Paget's deforming osteomyelitis in the proximal portion of the right femur, namely, heavy and somewhat irregular thickening of the cortex in the proximal portion of the shaft, and heavy trabeculation of the head, neck and trochanter. No other evidences of the disease were found in the bones, roentgenographically. A vaginal examination by Dr. Ludwig Emge disclosed an exquisitely sensitive thickening about the right sacro-iliac joint, running up on the ilium; but roentgenograms of the pelvis as well as of the tibiae and of the skull failed to reveal any further bone changes. Bimanual examination of the pelvic organs gave negative results.

The Wassermann test was negative. Roentgenograms of the teeth revealed rarefaction of the bone about a number of them.

The patient, when first seen (April 28, 1922) was lying doubled up in bed, with the thighs flexed on the abdomen. Any movement or manipulation caused great pain. This condition continued unchanged for several days.

Treatment.—May 2, the deformity was reduced under general narcosis, and a long plaster-of-Paris spica was applied. At the same time, all the remaining teeth were removed from the mandible. The pain now became less severe, but did not completely disappear, and the plaster spica was removed after about three weeks. Then followed a week's rest in bed.

May 31: Arthrodesis of the right sacro-iliac joint was carried out under general anesthesia. The operation was that devised by Smith-Peterson, with the lateral approach to the joint. The wound was closed, and a long plaster spica was applied. Considerable shock followed the operation, and there was some pain for several days. The plaster was removed, June 14, on account of symptoms of marked constitutional involvement—delirium, high temperature, etc. The wound had healed by first intention. The constitutional symptoms slowly subsided, and the patient gradually recovered, returning to work about four months after the operation. A recent letter from her states that, with the aid of Eddyism, she is progressing favorably.

The piece of bone removed from the sacrum at the time of operation was decalcified, imbedded, cut and stained. With the exception of perhaps a slight widening of the haversian canals, nothing abnormal could be distinguished. The marrow was of the lymphoid variety, and was normal.

The peculiar thing about this case is that the bone changes were demonstrated in the femur alone. The symptoms referred to the sacro-iliac joint, as well as the mass felt in the vicinity, pointed to involvement of the ilium; but no bone changes could be distinguished there in the

roentgenogram, and at the operation I used the iliac bone fragment to produce ankylosis of the sacro-iliac joint, and did not feel justified in removing a piece of it for study.

CASE 4.—*History.*—M. B., a housewife, aged 50, first came to the clinic, Sept. 6, 1922, complaining primarily of a sensation "as if something wanted to pull

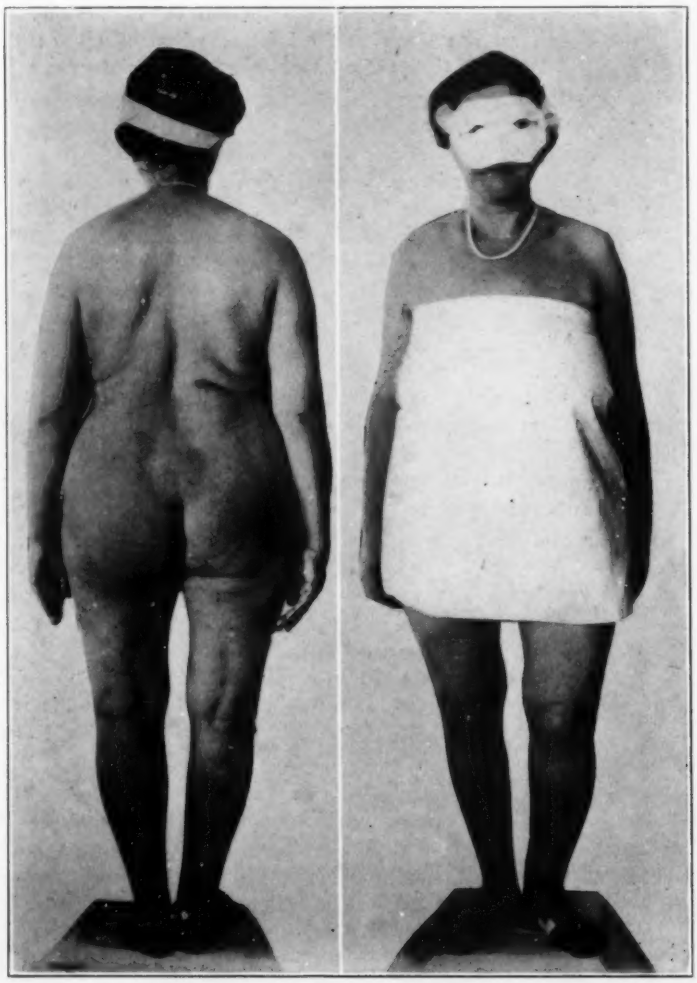

Fig. 6 (Case 4).—Front and back views.

out of the left ear," and of postnasal catarrh. She had had a ringing in the ear for about two years. (It will be recalled that buzzing in the ears was an early symptom in Case 1). A diagnosis of chronic nonpurulent aural catarrh was made. The patient was not seen for about a month. October 3, she returned, complaining of pain in the back, which, she said, had been present

for about four years. She gave the following history: Her mother was alive; her father died at 55, of bronchitis, the patient thought. One brother died of pleurisy, another of bronchitis. The patient was married at 15, had a child at 17, and had never been pregnant since. She had previously been in good health, though the tonsils had been bad for years. She had had frequent attacks of tonsillitis and of quinsy. The tonsils were removed one year previously. All the upper teeth were extracted about three years previously, on account of pyorrhea.

The pain started gradually in the back, four years previously, without history of injury. It was dull, and was worse when the patient stood or walked. The left leg was swollen and painful, and "got stiff." The pain, which ran

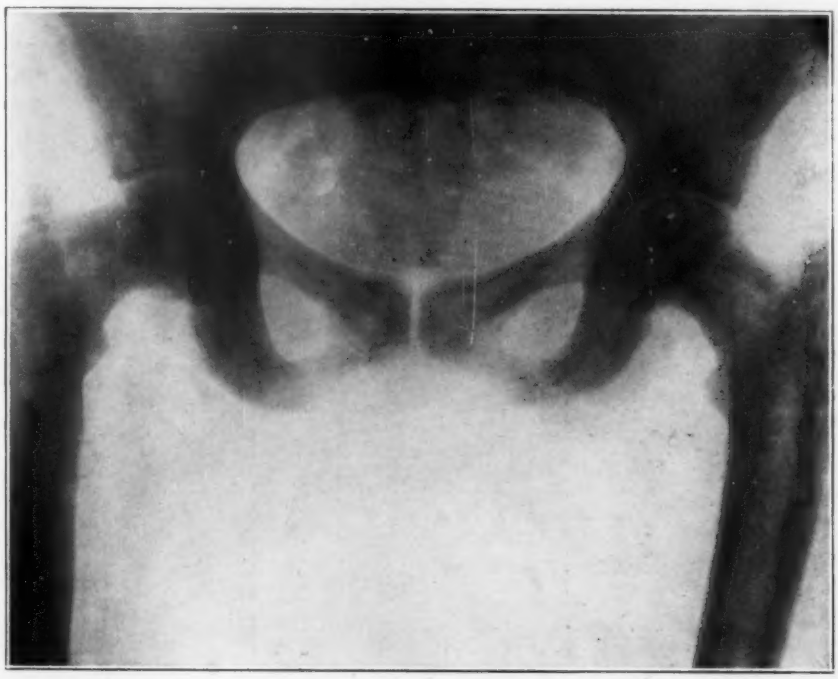

Fig. 7 (Case 4).—Appearance of pelvis and proximal end of femora.

down the left leg to the foot, was growing worse, and at times caused the patient to limp. On questioning, she admitted that she was becoming shorter and for the past three and one half years had been growing bow-legged.

As the patient stood, she presented a lateral curve to the left in the lumbar region. All motions of the spine caused pain referred to the left sacro-iliac region. The Kernig sign was negative. The left tibia was slightly rotated outward, and was 1.5 cm. shorter than the right. About the middle, it presented a rather well marked thickening anteriorly, quite sensitive to pressure. Abduction was limited in both hips, as was rotation.

The roentgenograms revealed a thickened cortex in the middle third of the tibia on all sides, with some forward bowing, and an irregularity of outline of

the fibula. Other roentgenograms taken later showed changes characteristic of Paget's deforming osteomyelitis in the skull, mandible, femora, pelvis, spine, radii and humeri; evidences of the second great type of arthritis in the spine, and calcification in the pineal gland.

The dental clinic reported alveolar infection, and removed buried roots from the upper jaw, and one tooth from the mandible.

Fig. 8 (Case 4).—Appearance of leg bone.

Examinations in the women's clinic and examination of the stools for parasites were negative. The medical clinic reported a basal metabolic rate of +8 per cent.

SUMMARY

The first patient was a man whose mother died of cancer. He probably never had had syphilis, though his wife had miscarried repeat-

edly. The disease began at about the age of 50, with pain in the back, and involved many bones. It lasted for about thirteen years. Infection in the alveolar processes of the jaws was noted during life, and at necropsy, when nephritis, cholelithiasis and liver abscesses were also noted.

Fig. 9 (Case 4).—Appearance of base of skull and cervical spine. The second type changes in the cervical spine are evident.

The second patient, a man of 47, whose father had died of cancer, presented no evidence of syphilis. The disease began at about the age of 34, with pain in the back, and involved many bones. The patient had well marked infection in the alveolar processes of the jaws, and chronic spinal arthritis of the great second type. He was alive at the last note.

The third patient, a woman of 61, whose family history was apparently unimportant, developed the disease at about the age of 60, with pain in the back, or with pain in the knee, and it presumably affected but one bone, or possibly two bones, the femur and the ilium. The patient had an infection in the alveolar processes of the jaws, and a second type arthritis in the knee. She presented no evidence of syphilis. The dead teeth were all removed, and the sacro-iliac joint was ankylosed by an operation. She improved markedly, and at last account had returned to work.

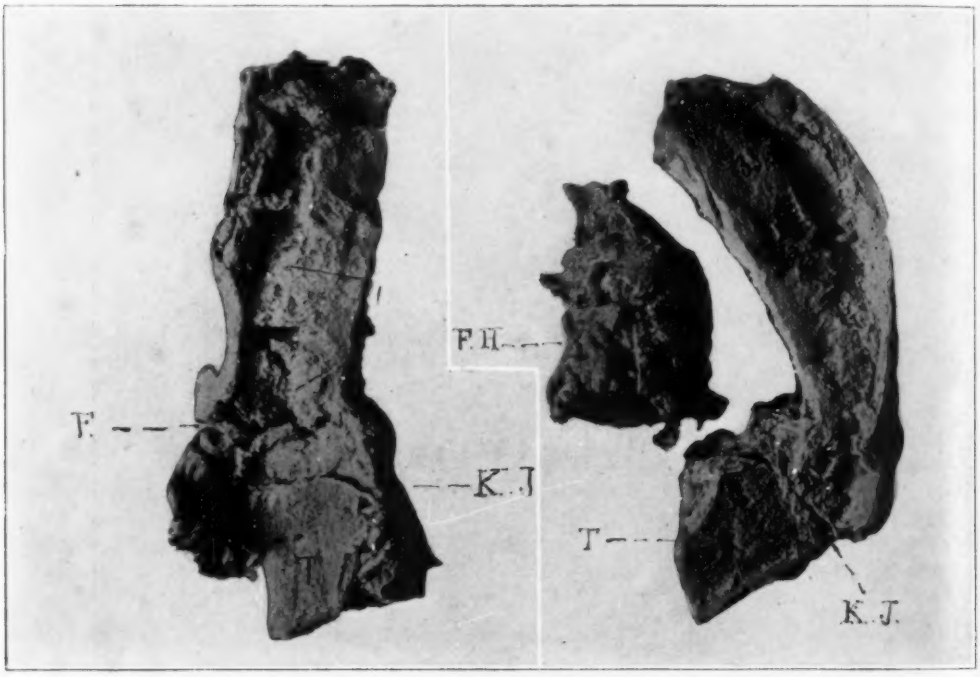

Fig. 10 (Dr. Smith's case).—The two halves of specimen sawed sagittally; *T*, tibia; *K J*, knee joint; *F*, fracture; *F H*, femur head and neck.

The fourth patient, a woman of 50 years, whose family history is not suggestive, developed the disease at the age of about 46, with pain in the back, and it involved many bones. She had also chronic multiple arthritis of the great second type, calcification of the pineal gland, and infection in the alveolar processes of the jaws. No evidence of syphilis was present, and the stools were negative for parasites. The dead teeth were removed, and parathyroid extract was administered. She improved during the three and one-half months of observation.

Two of the patients were men, two women. The age of incidence was presumably 50, 34, 60 and 46. Two had cancer in the family

history; all had infection in the alveolar processes of their jaws, and three had also chronic arthritis of the great second type. In the first patient, this last point was not noted. In all, the disease began with pain in the back; in three, it involved many bones; in one, it involved one bone or possibly two.

To these histories I add notes on a specimen of a femur from another case, presented to me by Dr. Ethan H. Smith.

The femur was obtained from a hip joint amputation in a man of 55 years, in whom the disease had lasted for "at least thirty years." No other bone was involved. Amputation was performed on account of pain, and because of the failure of a subtrochanteric fracture to unite. At operation, the bone was found to be very soft. As. Dr. Smith expressed it: "The head of the femur could be simply pinched off." He found an old hematoma surrounding the fracture.

The specimen was in two parts, the distorted and hardly recognizable femur head, and the distal end of the femur with the proximal end of the tibia. The

Fig. 11.—Appearance of lower extremity of Dr. Smith's patient, from whom the specimen was taken. This photograph was taken in 1906, and the disease then was presumably of about twenty years' standing. Eight years later, the femur was fractured distal to the trochanters. The fracture did not unite.

femur was bowed, shortened, much thickened and otherwise changed in its shape. It presented near its distal end a fracture, of which there is no mention in the history, and about which there is no evidence of any effort at repair. Presumably it occurred postmortem. The bone was very soft, and cut easily with a knife. When sawed sagittally, the remarkable change in its structure was evident. The entire architecture was altered. The femur was increased in diameter, and the cortex greatly thickened and irregular. The posterior cortex was about 2 to 3 cm. thick, and the anterior less than 1 cm. The irregularity in thickness of the cortex was due to the irregularity of contour of its inner surface.

The fracture mentioned in the history was an oblique subtrochanteric one, and showed no sign of any attempt at union.

Sections of the anterior cortex showed the absence of any compact bone whatever. The cortex consisted of scattered bone trabeculae without any definite arrangement. Some of the trabeculae showed so-called osteoclasts in

Howship's lacunae. The marrow consisted of a delicate reticulum of connective tissue, with here and there areas of cellular infiltration. Small hemorrhages had occurred into it.

COMMENT

The cause of this disease has been the subject of much discussion. Syphilis has been suggested, but this theory has been more or less

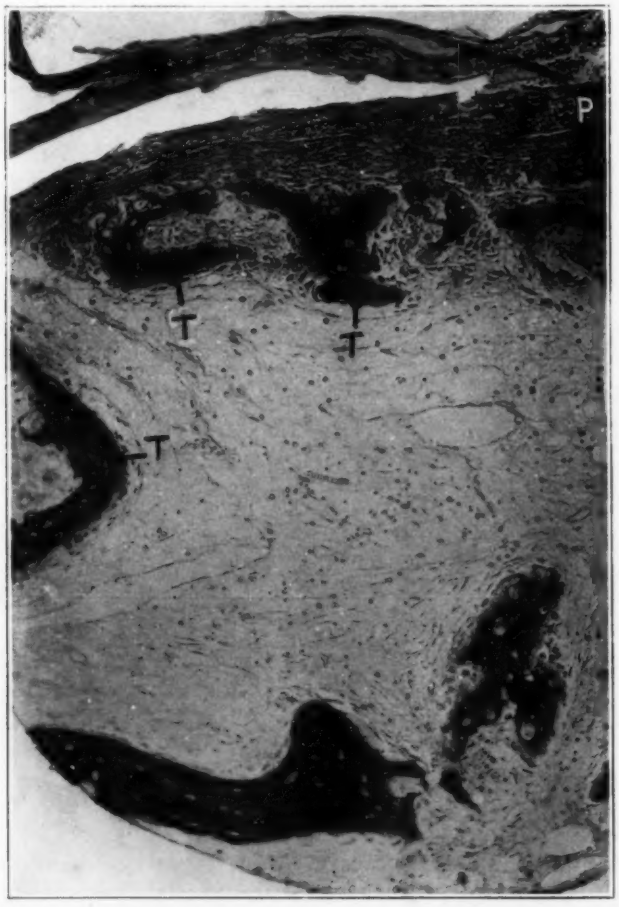

Fig. 12.—Low power photomicrograph of stained slide of a section from the cortex of the femur shown in Fig. 10. The cortex as such has ceased to exist. Under the periosteum are seen a few scattered poorly formed trabeculae, *T, T, T*. The marrow consists of little else than fibrous tissue; *P*, periosteum.

generally abandoned. It could not be diagnosed with reasonable probability in any of my cases. To external inspection, the appearance of the long bones suggested syphilis, but the roentgenographic picture was quite different, and the anatomic changes also. Perhaps the greatest

argument against its syphilitic nature is the failure of antisyphilitic treatment.

Paget drew attention to the fact that his early patients all died of a malignant growth. Other observers have noted the same fact in their cases; and a study of the reported cases of the disease shows the peculiar sequence, never invariable, running through them. It is probable, therefore, either that Paget's deforming osteomyelitis may cause cancer, or that the same cause may be responsible for both diseases. A family history of cancer was obtained from two of my patients.

Ziegler and others have pronounced the bone changes similar to those observed in the second great type of arthritis. On the other hand, this similarity has been denied. The two diseases occurred together in the three of my patients in whom a search for arthritis was made. Certainly both have all the ear marks of a chronic inflammation in the marrow caused by something other than bacteria.

All four of my patients had evidences of osteomyelitis at the roots of their teeth. Generally, the condition of the teeth is ignored in the histories of the reported cases. Vogel, Hartmann and Kutscha indicate that their patients had alveolar infection, Mackey says his patient's teeth were sound. I have repeatedly called attention to the almost invariable presence of alveolar infection in patients with the second great type of arthritis.[1] It is not that the osteomyelitis in the jaw, of itself, acts as the cause, but that it serves as the open door through which the nonbacterial organism enters to infect the bone marrow. What this organism is we have not yet succeeded in determining, and we may only surmise whether the same organism causes chronic arthritis and Paget's deforming osteomyelitis, and possibly cancer also. This line of investigation is much more promising than those proved erroneous, such as syphilis, and much more definite than "disturbed metabolism" or "rheumatic diathesis."

The three patients in this series seen during the past year all had the benefit of our knowledge, recently acquired, of the relation of alveolar infection to the chronic, nonbacterial inflammations in bones, and had the affected teeth extracted as the first step in the treatment. Improvement followed in two cases. The third patient disappeared. If this article should fall into the hands of some one to whom he presents himself for treatment, I shall appreciate any information about him. His name is Banforth. He can be recognized from his photograph.

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1. Ely, L. W.: Second Great Type of Chronic Arthritis, Arch. Surg. **1**:158 (July) 1920; California State J. Med. **19**:415 (Oct.) 1921; Amoeba as Cause of Second Great Type of Chronic Arthritis, California State J. Med. **20**:59 (Feb.) 1922; Inflammation in Bones and Joints, Philadelphia, J. B. Lippincott Company, 1923, p. 426.

Another promising field for investigation in these cases is the presence of parasites in the gastro-intestinal canal. So far, our search has been in vain, but that does not mean that they are necessarily absent. They are frequently present in patients afflicted with the second great type of arthritis, and are probably responsible for the areas of aseptic

Fig. 13 (Case 5).—Front and lateral view of patient.

necrosis which constitute the primary pathologic lesion in that disease. In certain cases, they may be in the mouth only, and then, of course, would not be revealed by our stool examinations. Proof of this will be hard to secure, for apparently parasites are short lived in the marrow, and are extremely difficult to recognize when they are

present. Authorities on parasitology differ in their opinion of the specimens I have submitted to them. The task will be even more difficult in Paget's deforming osteomyelitis, for we have not yet found any definite pathologic change except the fibrosis of the marrow, and the irregular production and absorption of bone.

In the marrow, of course, we must search for the seat of the difficulty, for the bone simply reacts to disease in its contained marrow, and

Fig. 14 (Case 5).—Appearance of femur.

nothing is ever learned from its study except that it is or is not being properly built up and torn down. Both the building up and tearing down are accomplished through the activity of the marrow.

A recent writer has thrown out a large number of the published cases of Paget's disease, using some criterion of his own. A typical case, such as my first and second, can be recognized immediately from an inspection of the patient, and this was the invariable method of

diagnosis until the introduction of the roentgen rays; but my fourth patient showed only a suggestion of the disease in her photograph, although her bones are extensively involved. In her case, as in that of the third patient, the diagnosis was made by the roentgen rays, and this is the only reliable means at our disposal. Certainly the involvement of many bones is not necessary. The specimen of the femur described here showed absolutely typical bone and marrow changes, but it was the only bone involved.

A good working definition of Paget's deforming osteomyelitis is: a chronic inflammation of the bone marrow, akin to that found in the second great type of arthritis, involving a single or many bones. It occurs in middle or later life, affects men more often than women,

Fig. 15 (Case 5).—Appearance of pelvis and hips.

and is probably caused by some nonbacterial organism which gains access to the system through the sockets of dead teeth.

While the report of these cases was in the hands of the editor awaiting publication, another patient with this disease presented himself at the clinic.

Case 5.—*History.*—A waiter, aged 58, stated that the right leg for the past fifteen years had been growing shorter "by itself," and had become very bowed. The knee had swelled, but had not been painful.

Examination.—There was a marked limp, and barrel chest. The trunk was short, the head slightly pear shaped. The lower ribs were just within the flare of the ilia. The right femur was bowed outward and anteriorly. The right knee was decidedly enlarged, and in slight flexion. It crepitated loudly on motion, and was slightly limited in extension and markedly so in flexion. The

Fig. 16 (Case 5).—Appearance of knee.

Fig. 17 (Case 5).—Appearance of cervical spine.

right thigh muscles were atrophied, and the right hip was limited in motion in all directions. The entire spine was rather bowed, and was limited in its motions throughout its length, except in its uppermost and lowermost joints. The patient moved stiffly. All the upper teeth were gone, and the condition of the lower ones was suggestive of infection. The right trochanter was above Nelaton's line. The right lower extremity measured 90.5 cm., the left, 88.5 cm.

Dental examination revealed abscesses at the roots of most of the remaining teeth. The Wassermann test was negative. The leukocyte count was 7,050. The basal metabolic rate was 18 per cent. Examination of the stools revealed *amoeba coli*. The roentgenograms revealed typical changes of Paget's deforming osteomyelitis in the spine, femora, pelvis and calvarium. Arthritis of the great second type was also noted in many of the joints.

A FUNDAMENTAL FACTOR IN THE RECURRENCE OF INGUINAL HERNIA*

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The modern operation for the repair of inguinal hernia may be said to date from 1889 and 1890, when Halsted and Bassini published their studies. It may also be said with assurance that the thirty odd years' experience gained from the performance and study of this operation has taught surgeons that the fundamental principles underlying the permanent operative cure of hernia are: (1) high ligation of the sac; (2) adequate reinforcement of the defective abdominal wall, and (3) primary wound healing.

No one of these three requirements is particularly elusive, nor does any one of them seem difficult of accomplishment. Yet the percentage of postoperative recurrences is far from encouraging. Unfortunately, there exists a disconcerting divergence of opinion regarding the frequency of recurrence, a divergence which ranges all the way from 0.8 to 12 per cent., both groups of figures coming from surgeons of enviable reputation. One cannot help feeling that the higher percentage is, of the two, the more entitled to credence. Inquiries regarding postoperative recurrences are usually made by letter, and the patients' replies are credited at their face value, in spite of the fact that the patient himself is a most untrustworthy judge of early though definite recurrence. Our recent experience with draft men demonstrated the incredibly large percentage of hernias existing without any knowledge of their presence on the part of men affected.

Even more convincing to us than figures covering the frequency of recurrence is the almost incalculably large number of modifications of the Bassini operation that have been devised and described. It may be said of surgery as of medicine that a multiplicity of remedies for any one disease indicates, almost beyond doubt, that none of the remedies is thoroughly satisfactory. Kocher, MacEwen, Andrews, Ferguson, MacArthur, Championnière, McBurney, Pitzman, Hoguet, Downes, Stettin, Harrison, Woelfler, Fournel, Quain and LaRoque are among the authors suggesting modifications of technic. In practically every instance, the modification is aimed, not at simplification of the operative procedure, but at reducing the rate of recurrence. We have included in this list of names no one who has suggested a modification of technic

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to meet a special indication, such as arises in sliding, voluminous bladder or bilocular hernia. In a recent and exhaustive study, Oudard and Jean reach the conclusion that "the Bassini operation ought to be abandoned."

If we accept as true the statement that high sac ligation, restoration of the abdominal wall and primary wound healing are the essentials to

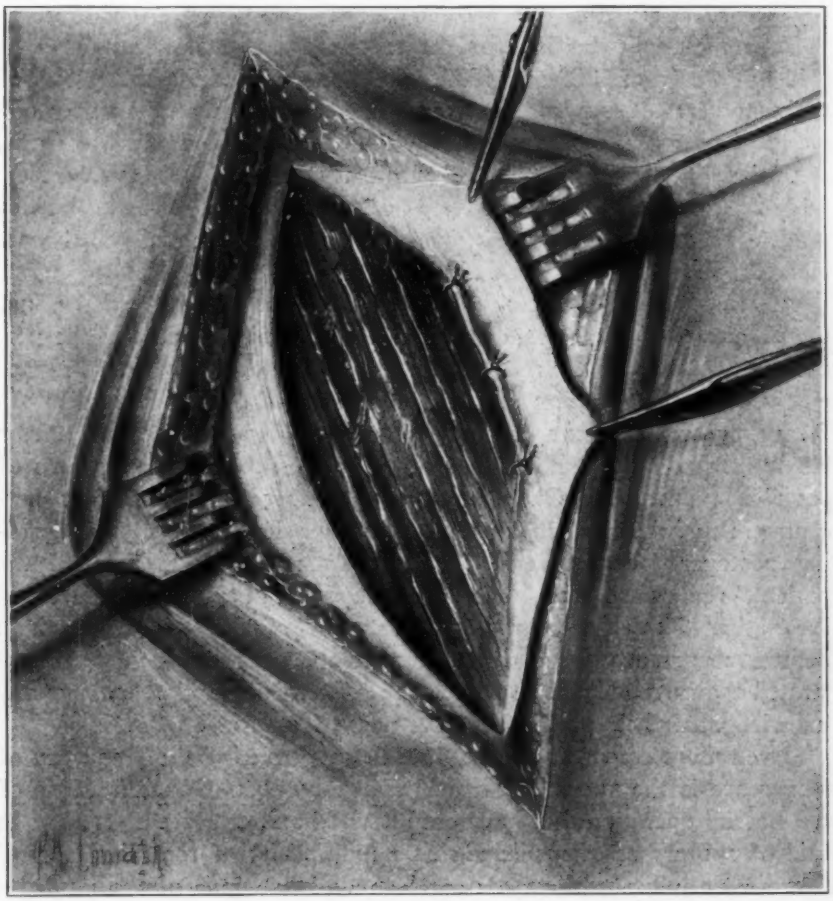

Fig. 1.—The fascia lata of the thigh is incised, and one edge is folded back on itself. The reduplicated edge thus formed, in imitation of Poupart's ligament, is then sutured to the underlying musculature.

perfect cure, it is clearly evident that proper sac ligation and proper wound healing are to the largest degree under the control of the surgeon. Both of these factors may be dismissed as comparatively insignificant agencies in the causation of recurrence. May the same be said of the restoration of the defective abdominal wall? For over thirty

years, this restoration has been effected mainly by suturing the internal oblique and transversalis muscles and their conjoined tendon, to the inguinal ligament of Poupart. Does this procedure (the main reliance of the surgeon in the modern hernia operation), really accomplish the intended purpose?

The answer to this question may be sought in the operating room and in the laboratory. For several years, one of us (M. G. S.) has directed attention to the relationship between Poupart's ligament and

Figure 2

Figure 3

Fig. 2.—Interrupted catgut suture of fascia to muscle; wound clean (two months after suture).

Fig. 3.—Interrupted silk suture of fascia to muscle; wound clean (four weeks after suture).

the internal oblique and transversalis muscles and their conjoined tendon. In none of his operations in recurrent inguinal hernia, has he ever seen these muscles and the conjoined tendon firmly attached to Poupart's ligament. In practically all instances, these structures are

widely separated, just as if they had never been approximated by suture. More than that, Poupart's ligament almost invariably appears strikingly intact and free from thickenings or adhesive cicatricial bands such as one might naturally expect. Coley [1] states that the muscles remain attached to Poupart's ligament, and he bases his statement on the two facts that his recurrence percentage is small and that in his operations for recurrence he finds the internal oblique muscle "firmly united to Poupart's ligament, nearly down to the pubic bone." We

Figure 4

Figure 5

Fig. 4.—Interrupted silk suture of fascia to muscle; wound clean (five weeks after suture).

Fig. 5.—Continuous silk suture of fascia to muscle; wound clean (seven weeks after suture).

doubt, though with hesitancy, the soundness of Coley's observation, just as, with hesitancy, we are inclined to question the value of his

1. Coley, W. B.: Keen's System of Surgery, Philadelphia, W. B. Saunders Company, **3**:77, 1908, and Progressive Medicine, Philadelphia, Lea & Febiger, 1922, p. 36.

statistical methods in arriving at the conclusion that his recurrences numbered only six in 740 operations (0.8 per cent.).

Several of our colleagues have stated that, in their operations for recurrent inguinal hernia, they also, as a general rule, find Poupart's ligament smooth, glistening, and free from attachments to the muscles to which it had been sutured previously. Oudard and Jean [2] report an

Figure 6

Figure 7

Fig. 6.—Interrupted silk suture of fascia to muscle; wound clean (seven weeks after suture).

Fig. 7.—Interrupted silk suture of fascia to muscle; wound clean (eight weeks after suture).

experience similar to mine. They find no trace of union between Poupart's ligament and the muscles in their operations for recurrence.

2. Oudard and Jean: Hernies Inguinales Récidivées, Rev. de chir. **60**:143, 1922.

Harrison [3] also says that a careful study of approximately 100 operations for recurrent inguinal hernias (personal communication) has convinced him that the suture of Poupart's ligament to the abdominal muscles does not result in a permanently close apposition of these structures.

In operating for recurrent hernia, one usually encounters rather dense scar tissue union between the posterior surface of the external oblique fascia and the underlying sheath of the internal oblique and

Figure 8

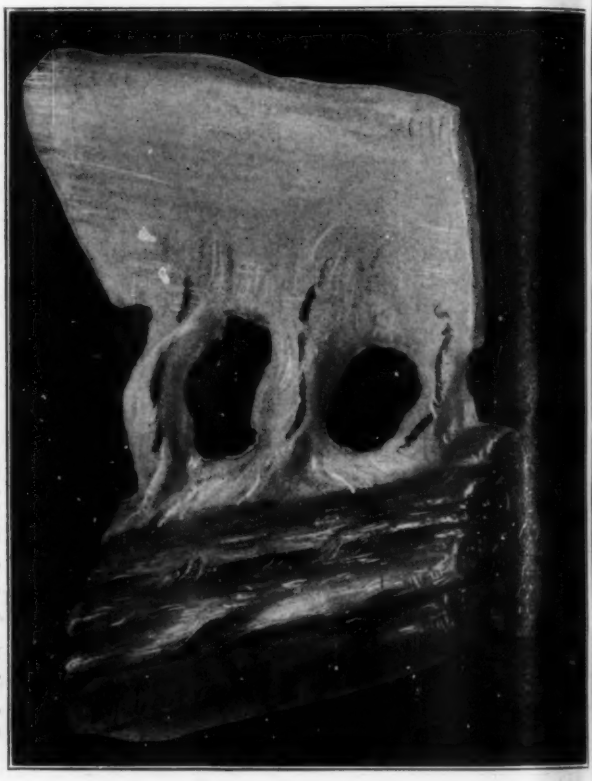

Figure 9

Fig. 8.—Interrupted silk suture of fascia to muscle; wound infected (nine weeks after suture).

Fig. 9.—Interrupted silk suture of fascia to muscle; wound badly infected (ten weeks after suture).

transversalis muscles. These dense adhesions usually create the unfortunate impression that the tissues are "glued together"; but if one will

3. Harrison, P. W.: Inguinal Hernia: Surgical Treatment, Arch. Surg. **4**: 680 (May) 1922.

patiently divide these superficial adhesions and thus release the outer flap of the external oblique, he will find that it leads him down to an unattached Poupart's ligament.

Why should this be the case? It goes without saying that if the muscles are anchored to Poupart's ligament under tension, the union will be an uncertain one at best. But is tension the only factor that militates against union? Exactly what happens when muscle is sutured

Figure 10

Figure 11

Fig. 10.—Continuous silk suture of fascia to muscle, which was traumatized by wedge excision; wound infection (seven weeks after suture).

Fig. 11.—Continuous catgut suture of fascia to muscle, which was traumatized by wedge excision; wound clean (three months after suture).

to fascia? A diligent search of the literature failed to bring to light a single study of fascia-muscle wound healing. It was necessary, therefore, to institute these studies in the laboratory, where fifty experiments were carried out on dogs, under ether anesthesia.

The inguinal canal of the dog is so snugly and completely closed as not to permit additional suturing. It was decided, therefore, to study the union of the fascia lata of the thigh to the underlying group of muscles. By a 3-inch (7.5 cm.) longitudinal incision at the anterior and upper portion of the outer aspect of the thigh, the fascia lata was exposed and incised longitudinally for about 2 inches (5 cm.). A free edge of the fascia was then folded back on itself, in imitation of the reflection of the external oblique fascia to form Poupart's ligament. The

Fig. 12.—Interrupted silk suture of fascia to muscle, which was traumatized by wedge excision; clean wound (eleven weeks after suture).

reduplicated edge of fascia was then sutured to the underlying muscle. This suture of muscle to fascia was always carried out, so that there was no tension whatsoever on the sutures, in order to obviate all possibility of the separation of fascia from muscle by pull (Fig. 1). Different types of suture (continuous, mattress and interrupted) and different types of suture material (catgut and silk) were used. In some of the experiments, infection was courted by slovenly technic, in order to observe the effect of suppuration on subsequent muscle-fascia union.

In another group of animals, the muscle was traumatized by excising a thin wedge and then the reduplicated fascial edge was sewed into the traumatized portion of the muscle. By this means, the influence of trauma on union could be observed. Finally, in another group of experiments, fascia was sutured to fascia in order to observe the type and strength of union that resulted. The topic of wound healing of fascia to fascia may be dismissed at this point with the statement that, in all the experiments, the union was perfect and strong, and so smooth that the site of suture could be determined with difficulty, even under the microscope. At the end of periods varying from one to three months, the animals were anesthetized and killed, and the fields

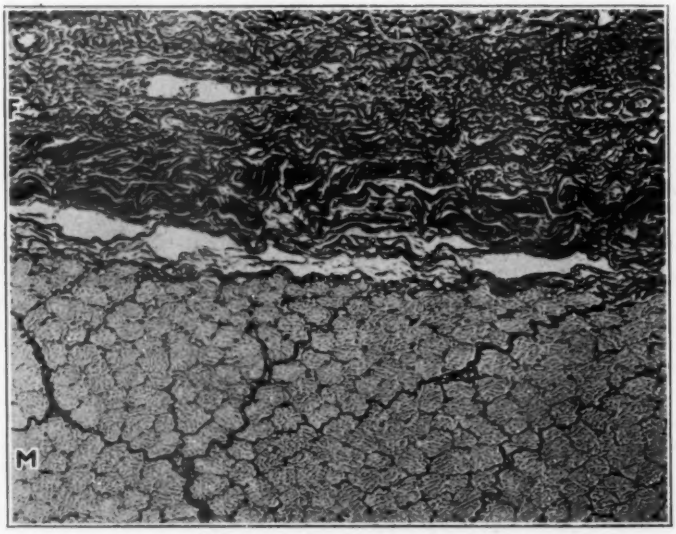

Fig. 13.—The normal separation of fascia lata from the underlying muscles; *F*, fascia lata, *M*, muscle.

of previous operative attack were studied, macroscopically and microscopically.

Figures 2 to 12 represent typical results in the final wound healing. These illustrations are self-explanatory and require little comment. However, by way of summarizing the result of the experiments it may be said:

1. In every instance of clean wound-healing, the fascia was widely separated from the muscle to which it previously had been sutured. A very thin and translucent membrane of areolar tissue bridged the gap between the edges of the fascia and the muscle. The nonabsorbable sutures usually cut their way through the muscle (it has already been stated that there was absolutely no tension on the suture line), and

hung in the fascial edge. In some instances, there occurred along the sutures a reactionary fibrosis, indicated by opaque white streaks in the delicate layer of areolar tissue already described (Figs. 4, 5, 6). It seemed to make no difference whether catgut or silk were used, or whether the suture was applied continuously or interruptedly. The

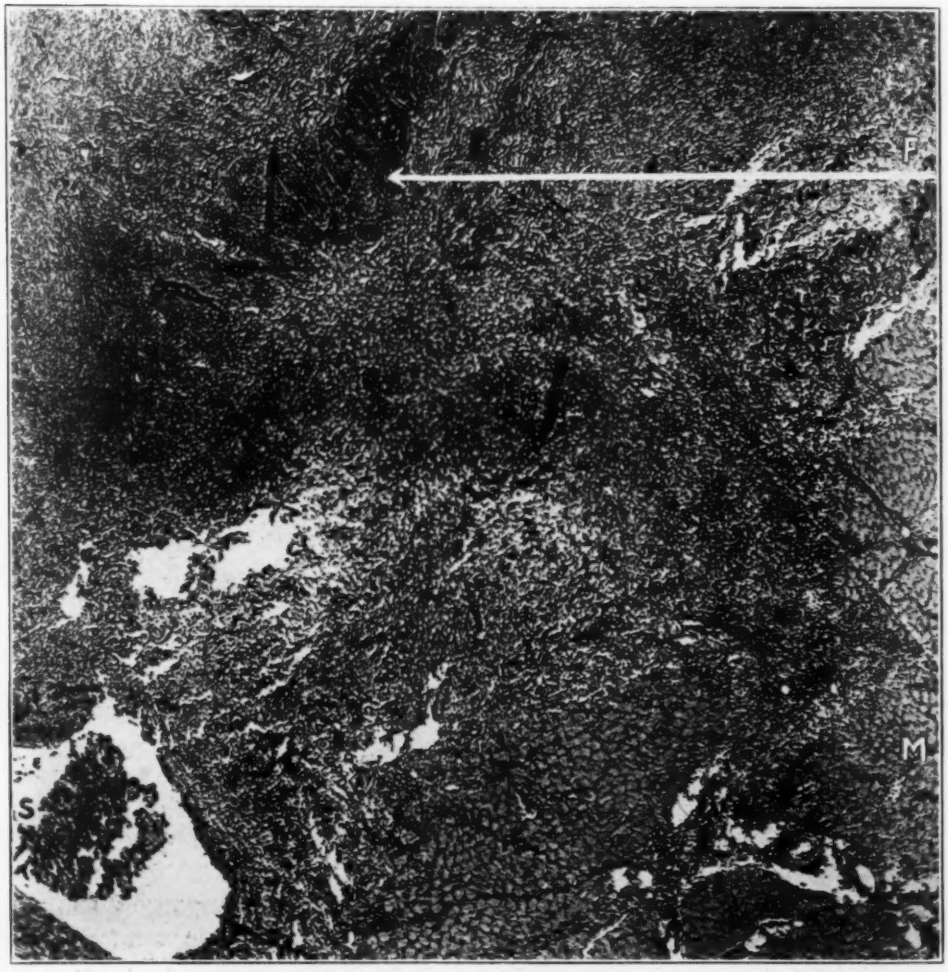

Fig. 14.—Condition of acute inflammation at the site of a suture, in the line of fascia-muscle apposition; *F*, fascia, *M*, muscle, *S*, suture (high power magnification).

muscle and fascia would not establish a close union, in wounds that healed by primary union.

2. In every instance of wound infection, the fascia was separated widely from the muscle to which it previously had been sutured. In

these instances of wound infection, the layer of delicate areolar tissue described above was usually absent; but the reactionary inflammation about the sutures was more marked than in the clean wounds. These streaks of heavy connective scar tissue bridged the space from muscle to fascia, as is shown in Figures 8 and 9. In no instance of simple

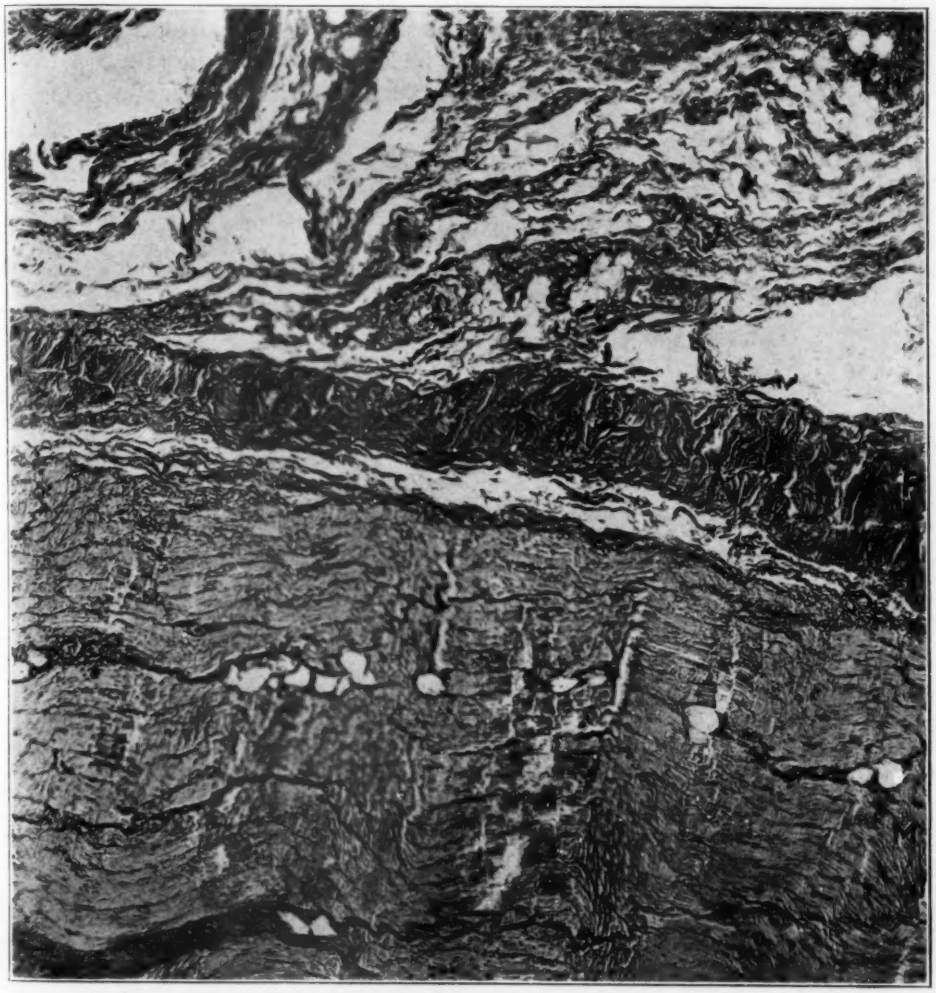

Fig. 15.—Site midway between two sutures, in the line of fascia-muscle suture; *F*, fascia lata, *M*, muscle (high power magnification).

suture, in which infection occurred, was there a solid sheet of heavy connective tissue uniting the edges of the separated muscle and fascia. In these infected wounds, therefore, we never saw either direct union of muscle and fascia or even continuous indirect union through a solid uninterrupted layer of cicatricial connective tissue.

3. In every instance in which the muscle was traumatized by the excision of a wedge so that the fascia could be sutured in the raw trough, there was an attempt at direct union between fascia and muscle. This union was complete (Figs. 10, 11, 12) in only one instance.

Before studying the wound healing microscopically, a histologic study was made of the normal relationship between the fascia lata and the underlying muscles, in a dog. This study showed that the fascia lata lies loosely on the muscle and is not only not united to it directly, but is really separated from it by loose areolar tissue (Fig. 13).

The histologic relationship between the fascia lata and muscle were then studied two weeks after suturing the muscle to the fascia with interrupted sutures. It was found that, along the sutures, there was an extensive reactionary, leukocytic (polymorphonuclear) infiltration (Fig. 14); whereas, between the sutures, the fascia merely lay against the muscle as it does normally (Fig. 15). In other words, the sutures

Fig. 16.—Pedicled strip of fascia lata lying in tunnel of muscle (traumatized muscle).

seem to set up a definitely limited inflammation which binds the muscle and fascia together at the immediate sites of the inflammation. Between these sites there is no union, and as the inflammation subsides, the binding power of the inflammatory exudate disappears.

From this group of experiments, therefore, it seems logical to infer that the mere apposition of muscle to fascia does not insure a firm and lasting union between these fundamentally different types of tissue. Wound suppuration seems to favor a partial cicatricial union. Trauma (to the muscle) seems to make it possible, in certain instances, to secure a direct and fairly strong union between muscle and fascia.

In view of the fact that the fascia unites with traumatized muscle (partially at least, in some instances, and firmly, in one experiment), it became necessary to study the details of wound healing in the presence of muscle trauma. In order to do this, a pedicled flap of fascia lata

was made; the underlying muscle was tunneled with a knife, and the fascial strip was laid in the raw muscle tunnel and sutured in situ, without tension, as shown in Figure 16. After periods of from eight to twelve weeks, the area involved was excised, and the relation between fascia and muscle was studied histologically. These studies showed that, wherever the fascial strip came into contact with intramuscular connective tissue (perimysium), it fused with it, and became firmly anchored (Fig. 17). Wherever the perimysial tissue was scanty, the fascial strip lay in its tunnel, with practically no evidences of union to the muscle about it (Fig. 18).

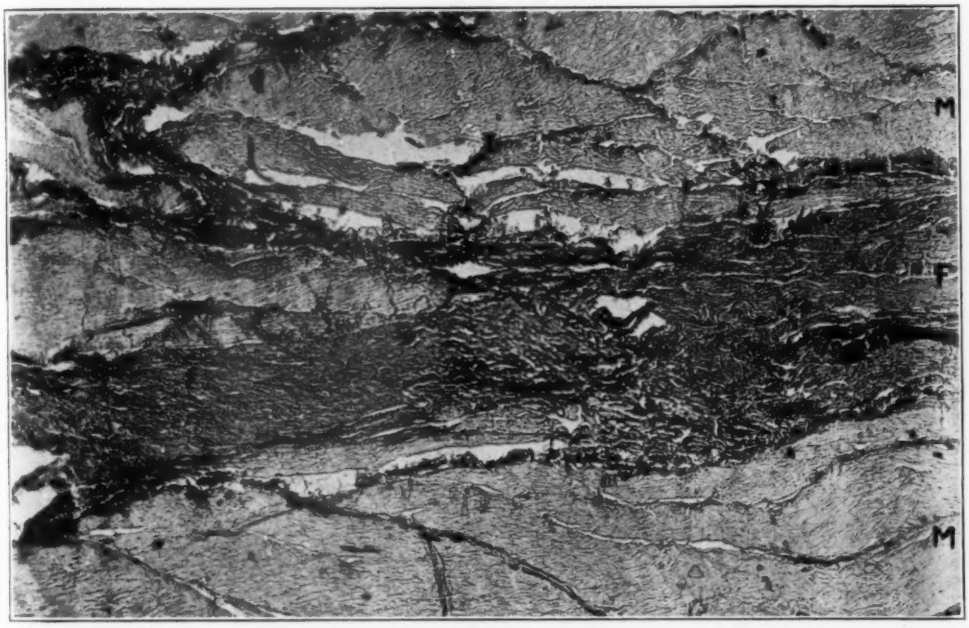

Fig. 17.—Fascial strip imbedded in muscle, which has been traumatized to make a tunnel for the fascia to occupy. The heavy strands of intramuscular connective tissue are fused with the fascial strip, firmly anchoring it; *M*, muscle, *F*, fascia.

The fact that simple apposition of muscle to fascia does not result in a firm union of these two structures is of fundamental importance, and is closely related to the problem of the radical cure of hernia. It is of interest to consider whether nature herself ever directly unites muscle firmly to connective tissue, and to determine how this union is normally established. We could think of only two sites in the human or in the dog where muscle and connective tissue were normally fused: (1) the close fusion of the rectus abdominis muscle with its connective

tissue sheath at the tendinous inscriptions, and (2) the close fusion of muscle and tendon where muscle ends and tendon begins.

As regards the rectus muscle and its union with the sheath of the rectus at the lineae transversae, Figure 19 clearly illustrates how a firm union is established. The sheath sends finger-like processes of connective tissue into the muscle belly. Each process is an integral part of the sheath itself. All along its course through the muscle, the tendinous process anchors itself in place by fusing with the various strands of connective tissue (perimysium) that course through the muscle and separate the various muscle bundles or fascicles. These

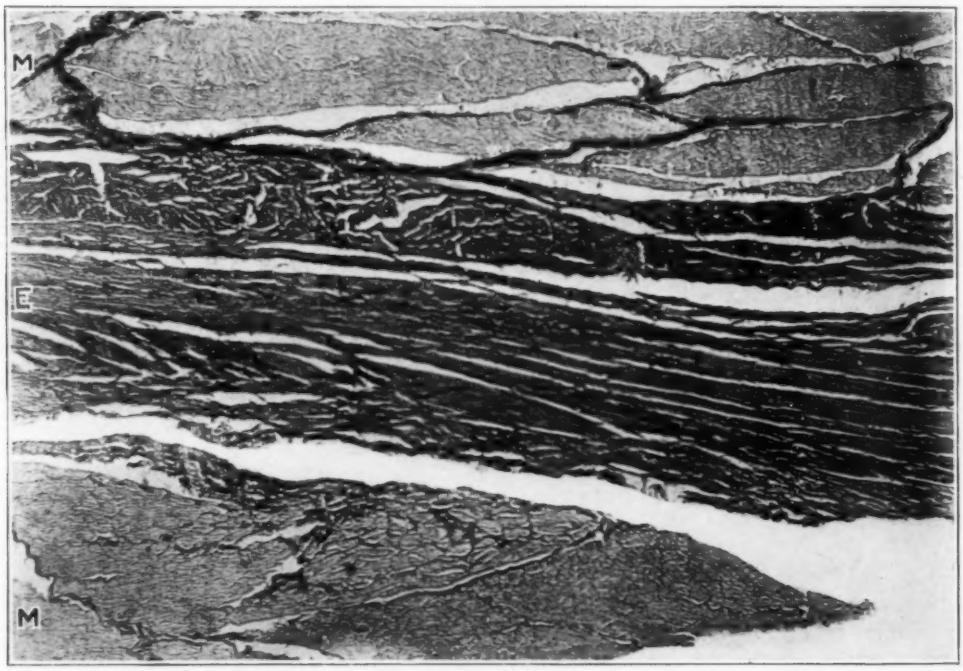

Fig. 18.—Same experiment as that shown in Figure 17, except that at this site the intramuscular connective tissue is scanty, and consequently the fascia is poorly anchored to the muscle; *M*, muscle, *F*, fascia.

various anchorages cause a firm union of sheath and muscle—a fact well known to surgeons, and necessitating sharp dissection, when the rectus is stripped from its sheath at the site of these transverse bands. A higher magnification shows with what care these anchorages are made by nature. Delicate connective tissue fibrils are given off by the tendinous bands and fuse with the connective tissue endomysium surrounding the smaller muscle bundles (Fig. 20).

The union of muscle and connective tissue at the site of muscle-tendon junction is somewhat after the same fashion and furnishes the

same type of histologic architecture as does the rectus muscle at the site of a tendinous band. Figure 21 is a low power magnification of tendon-muscle junction of the external oblique muscle of the abdomen, and shows how the tendon is directly continuous, both with a heavy central strand of connective tissue, running back for a long distance

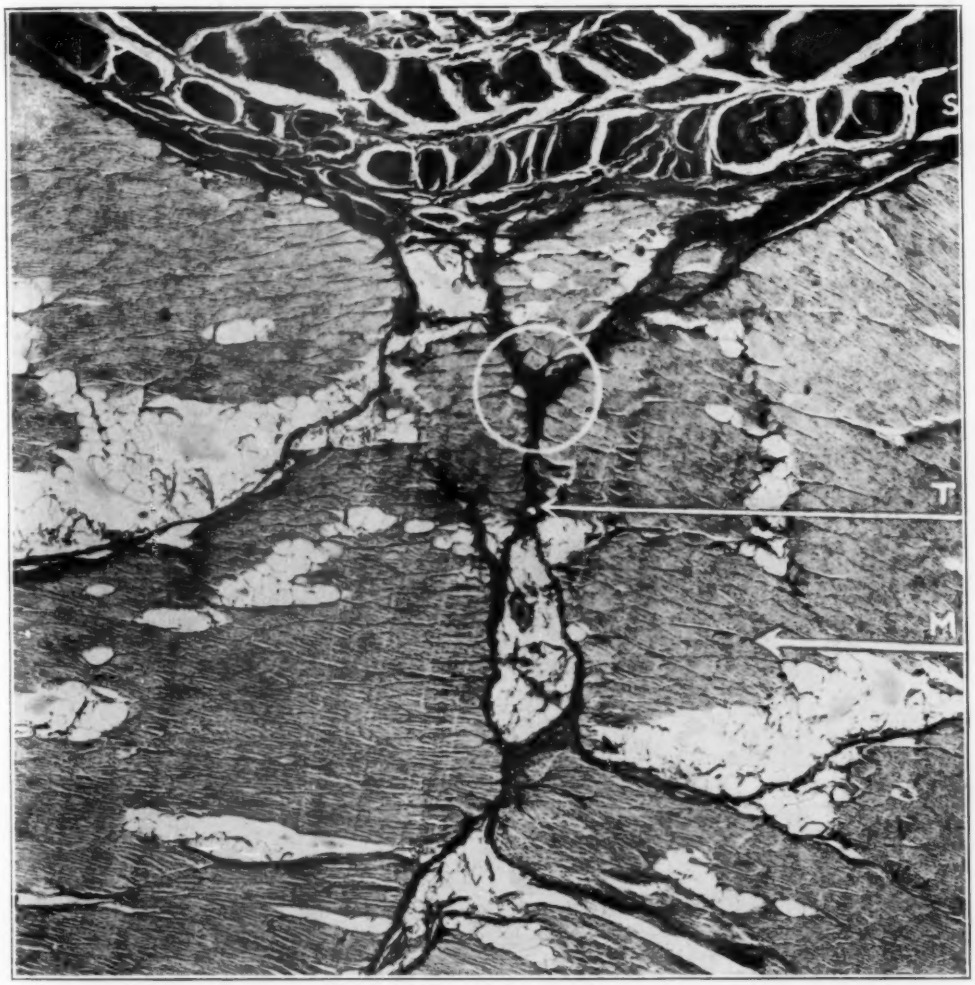

Fig. 19.—Anteroposterior section (low power) through rectus muscle and its sheath at the site of tendinous inscription, showing anchorages of tendinous band, both to the sheath and to the perimysial connective tissue of the muscle; *S*, rectus sheath, *T*, tendinous inscription, *M*, rectus muscle.

in the body of the muscle, and also with the sheath of the muscle that clothes its end and becomes continuous with the central strand of connective tissue. This type of union is very strong and can hardly be

duplicated by surgery. Figure 22 is a high power magnification of the same field and illustrates in greater detail nature's method of strengthening a muscle-connective tissue union. As will be seen in the illustration, the connective tissue system of the tendon is anchored at innumerable sites, to the connective tissue system of the muscle (peri-

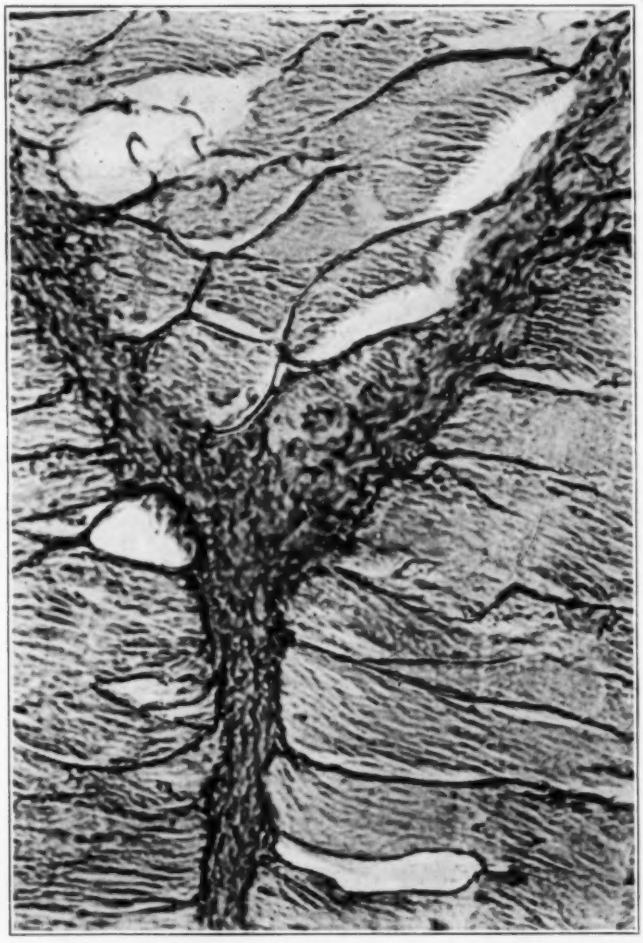

Fig. 20.—Lines of anchorage of connective tissue (tendinous inscription) to the muscle endomysium (high power magnification of the circled area in Figure 19).

mysium and endomysium and sheath), producing practically a continuity of muscle and tendon.

Up to this point, we have attempted to show that: 1. No success attended our various trials to establish a strong direct union between muscle and fascia except in those experiments in which the muscle was

traumatized previous to its suture to the fascia. 2. There are very few if any sites in the body where a direct muscle-connective tissue union occurs normally except in the muscle tendon system. 3. In these muscle-tendon systems, nature employs a definite type of architecture. This we in a measure imitate when we traumatize the muscle. But we cannot count on a full measure of success, even when we plan our

Fig. 21.—External oblique muscle and tendon of external oblique (abdominis) to show muscle-tendon junction (low power magnification).

experiments so that there is absolutely no tension at the site of apposition. It goes without saying that when tension is a factor, the sutured structures are very likely to pull apart before wound consolidation can take place.

Thus, we are led to the practical considerations of herniotomy. If the experiments here recorded have been executed properly, and if the conclusions from them have been drawn accurately, it is utterly

futile and useless to suture the internal oblique and transversalis muscles to Poupart's ligament. These muscles will not unite with the fascial ligament unless they have been deliberately and rather extensively traumatized, and even if they did unite the union would not be permanent on account of the inevitable tension that occurs when these structures are approximated. We do not believe that even the conjoined tendon often unites with Poupart's ligament when these two structures are sutured. These structures are both connective tissue, but in addition to the inevitable tension, which pulls against the suture line, there is

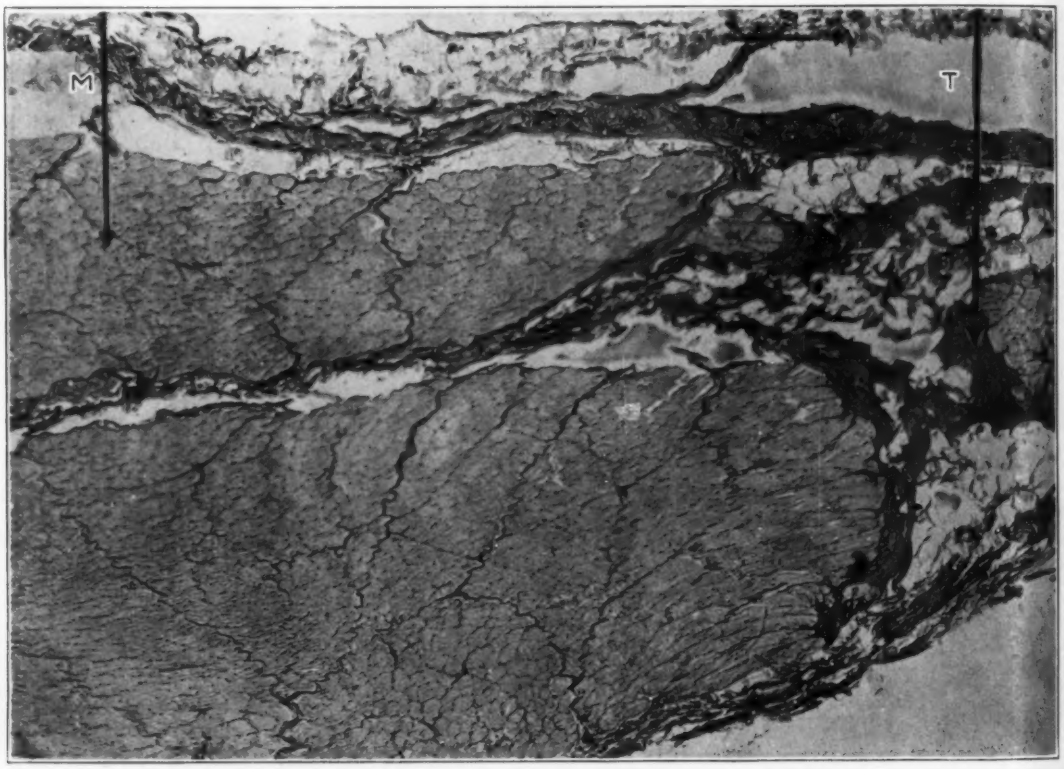

Fig. 22.—Tendon-muscle junction of external oblique (abdominis) muscle (high power magnification).

always present the possibility of the lateral and medial origins of the cremasteric muscle interposing themselves between Poupart's and the conjoined tendon, thus rendering union highly improbable (Fig. 23).

Must we then abandon the idea of reinforcing the weak abdominal wall? By no means. We have at our command three or four procedures:

1. We may rely on a strong union between Poupart's ligament and the outer flap of the external oblique muscle. This is a rational pro-

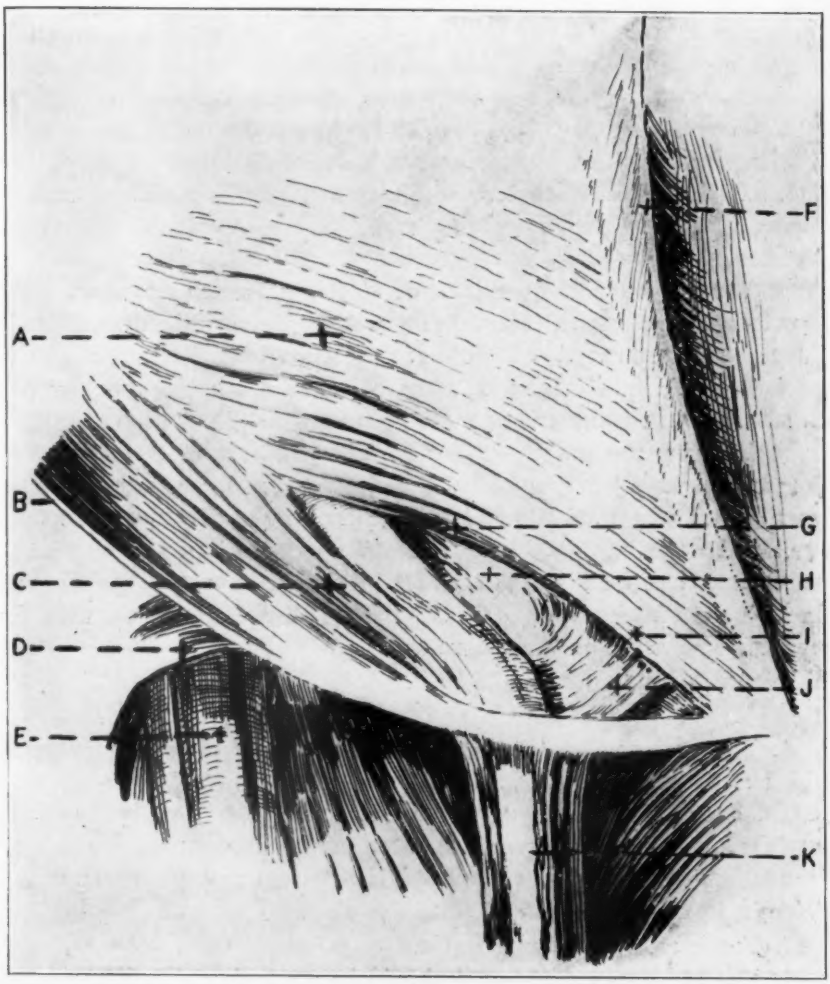

Fig. 23.—The inguinal canal (after Spalteholz), showing interpolation of medial and lateral origins of cremaster muscle, between conjoined tendon and Poupart's ligament; *A*, muscle obliquus internus abdominis, *B*, muscle obliquus externus abdominis (cut through and reflected downward), *C*, lateral origin of the muscle cremaster, *D*, margo falciformis (cornu superius), *E*, vena femoralis, *F*, muscle obliquus externus abdominis (cut through and reflected medianward), *G*, upper wall of the canalis inguinalis, *H*, posterior wall of the canalis inguinalis, *I*, conjoined tendon, *J*, mesial origin of the muscle cremaster, *K*, funiculus spermaticus with muscle cremaster.

cedure. It has been extensively employed in reinforcing the abdominal wall under the name of Andrews' modification, and our experiments show that its utility rests on the affinity of connective tissue for kindred connective tissue, in wound healing. We have been using a modification of this method with unqualified satisfaction, for the past two years, a period too short to permit of any more dogmatic statement.

2. We may employ the method of Pitzman [4] which depends on suturing the separated edges of the transversalis fascia, and ignores the internal oblique and transversalis muscles and their conjoined tendon. Pitzman very properly emphasizes the great strength of the transversalis fascia.

3. We may employ the method of Harrison [3] which also ignores the muscle-ligament suture and relies on the transversalis muscle-fascia suture, made after a plan somewhat different from Pitzman's.

4. We may follow the method of Slattery, which also relies largely on suture of the transversalis fascia.[5]

5. We may use the method of Gallie [6] who sutures the muscles to Poupart's ligament, but employs fascial strips as suture material. Our work shows why these strips should anchor tightly to Poupart's ligament and why they are likely to become well anchored to the intramuscular connective tissue with which they come in contact as they pass through the muscle. Gallie's method is, of course, bound up with the problem of tension on the suture line.

SUMMARY

1. The modern operation for the cure of inguinal hernia is attended with a disconcertingly high rate of recurrence.

2. Normal muscle will not unite firmly with fascia or ligament. It is, therefore, a useless procedure to suture the abdominal muscles to Poupart's ligament, in the hope of buttressing a weak or ruptured abdominal wall.

3. Fascia unites well with fascia.

4. The weak abdominal wall should be strengthened by the use of one of the methods of securing fascia to fascia approximation.

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EXPERIMENTAL CORD CRUSHES

WITH ESPECIAL REFERENCE TO THE MECHANICAL FACTORS INVOLVED AND SUBSEQUENT CHANGES IN THE AREAS OF THE CORD AFFECTED

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For several years, Dr. William Keiller, with whom I have been associated in the Department of Anatomy of the University of Texas, has contended, from his study of the spinal cords of patients who have died as a result of fracture of the spine, that, since the spinal cord is encased within a fairly firm but apparently slightly elastic tube of pia mater, the cord pulp formed at the site of lesion in crushes resulting in ribbon-like injuries takes the path of least resistance and tracks up and down the cord pushing aside and destroying cord elements. It was with this theory in mind that we undertook a series of experiments on dogs and of studies on human cords obtained fresh at necropsy, the purpose being to study the mechanical factors involved in spinal cord crushes both complete and partial, and the subsequent vital changes occurring in such injuries.

METHODS

Dogs were used for the experiments, and females were preferred because catheterization could be more easily carried out. In each of the dogs, a laminectomy was performed in the dorsal region of the spine at the level of the seventh and eighth vertebrae. The spinous processes were first removed and then the laminae were cut away, the dorsal aspect of the dura mater being thus exposed. In five of the dogs, such pressure was exerted with the tip of the finger that the body of the vertebra could be felt through the crushed cord. In three of the dogs, it was estimated that the crushes were partial, the cord being compressed to but one half of its anteroposterior diameter. The dogs were allowed to live variable lengths of time, from one hour to two weeks, and subsequently the spines were removed with the cord in situ. The human cords were obtained fresh at necropsy and were subjected to pressure between the fingers, the dura remaining intact. Both dog and human cords were then placed in 10 per cent. formaldehyd to harden, the dura being nicked at several levels to allow free access of the fixative.

After three days, the cords were removed and sections were made through, above and below the lesion. These were sectioned and stained with Delafield's hematoxylin and eosin or iron hematoxylin. For pur-

poses of study, the material may be divided into three groups: partial cord crushes in dogs, complete cord crushes in dogs and crushes of the human cord obtained fresh at necropsy.

PARTIAL CORD CRUSHES

EXPERIMENT 1.—*Operation.*—Dog 4, a small white female, pregnant, under ether anesthesia, March 24, 1923, was subjected to a laminectomy in the region of the seventh and eighth dorsal vertebrae. The dura was exposed and the cord was crushed until it seemed to the finger to be about one half of its diameter.

Result.—Eight hours after operation, the dog had apparently recovered from shock and was paralyzed below the site of operation. The reflexes (tendon

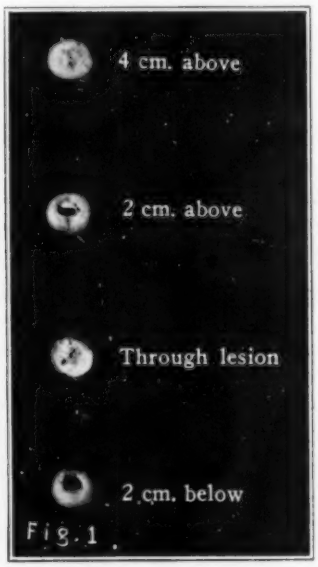

Fig. 1 (Dog 2).—Gross cord.

and sex) were present and active. The animal was killed by ether, the spine and cord being removed intact. It lived eight hours.

Gross Pathology.—There was slight deformity at the site of the lesion, with hemorrhagic areas of irregular type scattered above and below the lesion.

Microscopic Examination (Fig. 5, above).—At the lesion, there was destruction of the posterior white columns, with slight hemorrhage. There was marked edema of the remains of the posterior white columns and some of the lateral parts of the cord. Five-tenths cubic centimeter below the lesion, there was marked edema of the posterior white columns. Hemorrhage into central gray matter was noted. There was a curious lamination of the pulp, which had invaded the posterior columns in the ventral part. One half cubic centimeter above, there was a small amount of blood and pulp in the posterior central aspect of the cord, with edema in the posterior and lateral white columns.

EXPERIMENT 2.—*Operation.*—Dog 5, a small weak male, was operated on, March 24, 1923, under ether anesthesia, with the technic employed in Experiment 1, except that the cord snapped in two and separated slightly, being apparently brittle.

Result.—The reflexes in this case had become quite exaggerated before the spine and cord were removed twenty hours later, the paralysis being complete below the lesion. The animal had lived twenty hours.

Gross Pathology.—This was similar to that in Experiment 1.

Microscopic Examination (Fig. 5, center).—Through the lesion, there was rupture of the pia, and deformity of the cord, the wedged shaped dorsal columns being pushed back. The ventral aspect of the cord was destroyed. There was marked edema in the posterior and anterolateral white columns. Hemorrhage was noted along the line of the entering dorsal nerve roots and into the anteromedian fissure. One half cm. above, there was marked hemorrhage into the anteromedian fissure. Deformity of the ventral part of posterior white columns,

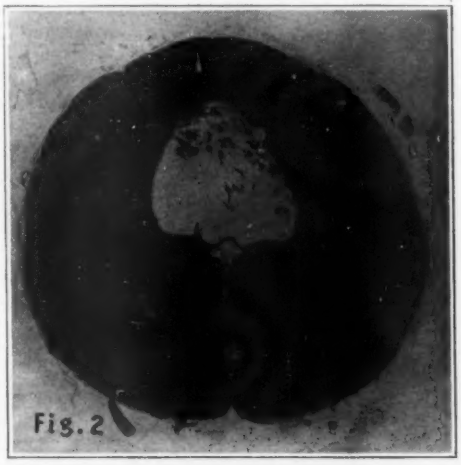

Fig. 2 (Dog 2).—Microscopic section, 2 cm. above lesion. Compare with Figure 9.

showing some pulp material, was present. Five-tenths cm. below, pulp was found in the posterior central part of the cord, and marked edema in the dorsal and lateral white columns.

EXPERIMENT 3.—*Operation.*—Dog 6, a large lively black male, was operated on, March 24, 1923, under ether anesthesia, with the technic employed in the case of Dog 4, except that after the cord was crushed, the dura over the site of lesion was incised, allowing the escape of cerebrospinal fluid.

Result.—At the end of thirty-two hours, bladder and bowel activity was automatic. The reflexes were as before. The animal lived thirty two hours.

Gross Pathology.—There was protrusion of the dorsal columns as a pointed process through the nick in the dura, with a gradual slope up and down the cord to normal.

Microscopic Examination (Fig. 5, below).—Through the lesion, there was apparent flowing of disintegrated and undisintegrated cord material toward the

nick in the dura. The pia was ruptured at this level over the dorsal columns. There was marked edema, with a long axis of spaces toward the nick in the dura. Less hemorrhage was noted than in previous cord examinations. Sections above and below the lesion showed some similarity of deformity of the dorsal columns, with much edema and slight hemorrhage.

EXPERIMENT 4.—*Operation.*—This was performed on Dog 6, after death by etherization, the site of operation being about 3 inches below that of the previous operation. The technic was that previously employed. The spine was removed with the cord in situ.

Gross Pathology.—There was slight deformity at the side of the lesion.

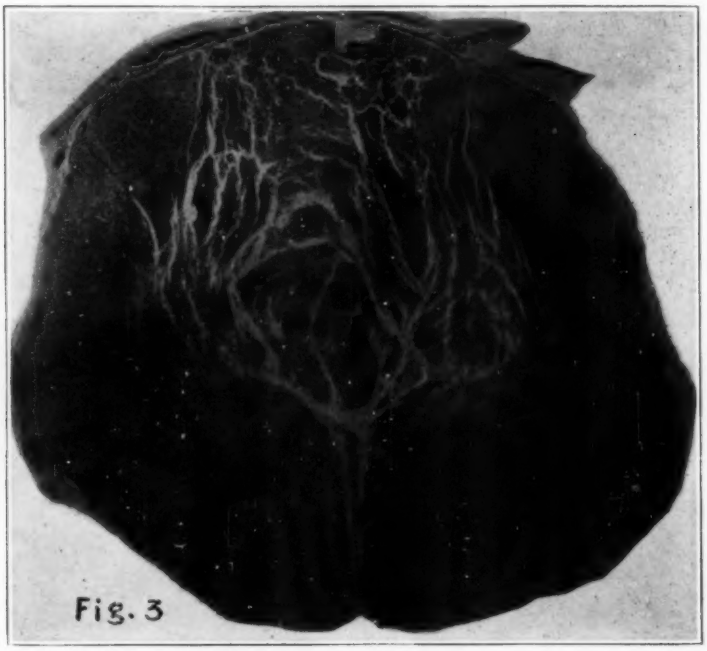

Fig. 3 (Dog 1).—Section 2 cm. above lesion. Lamination of invading blood and pulp is evident.

Microscopic Examination.—Through the lesion, there was deformity of the cord, but no evidence of hemorrhage or edema, such as would be expected. The same condition was present above the lesion. Five-tenths cm. below the lesion, there was a defect in one of the posterior gray horns, which gave the appearance of having been filled with disintegrated cord matter but which had been lost during the preparation of the sections. Examination of the gross specimen showed slight bulging of the corresponding area of the cut surface.

From an examination of the clinical data, it will be noticed that only a partial crush of the cord was intended. The first change to be noted was the presence of a deformed cord at the site of the lesion, the deformity affecting principally the dorsal white columns, though

in Dog 5 there seemed to be considerable destruction of the anterior white columns, due possibly to the fact that the cord snapped in two. The most marked change constant throughout the cords, with the exception, of course, of Experiment 4, was the presence of a fairly well marked edema involving the perivascular spaces and the nerve sheaths, located for the most part in the dorsal white columns, though the anterior and lateral white columns were also affected to a considerable degree, often giving a honeycombed appearance to these regions of the cord. Edema, as we use the term, is applied to the condition as Gordon Holmes describes it, with swelling of the axis cylinders and distension of the nerve sheaths, the latter sometimes being enormously distended, particularly in the lateral aspects of the cord, with no evidence of axis cylinders present. From our experiments, it will be

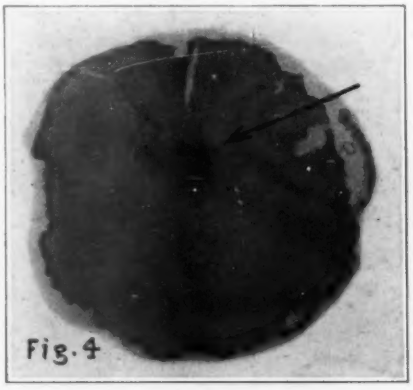

Fig. 4 (Dog 4).—Section 0.5 cm. above lesion. Arrow indicates blood and pulp area.

noted that the edema appears during the first eight hours after the lesion is produced, increasing in amount and area involved for at least two days. It is present above and below the lesion.

Hemorrhage is present in fair amounts, apparently most marked in the dorsal white columns and present above and below the lesion. The central gray matter is likewise involved in the hemorrhage, which is also scattered through the anterior gray horns. There is no massive hemorrhage.

Particular attention should be directed to the sections below the lesion in Dogs 4 and 5. The ventral part of the dorsal white columns seems to have been the seat of invasion by some cord débris, the fibers having been pushed aside and isolated; while in Dog 4 a distinct lamination of débris has occurred. The same state of affairs exists above the lesion in Dog 5. It is the presence of this cord pulp material

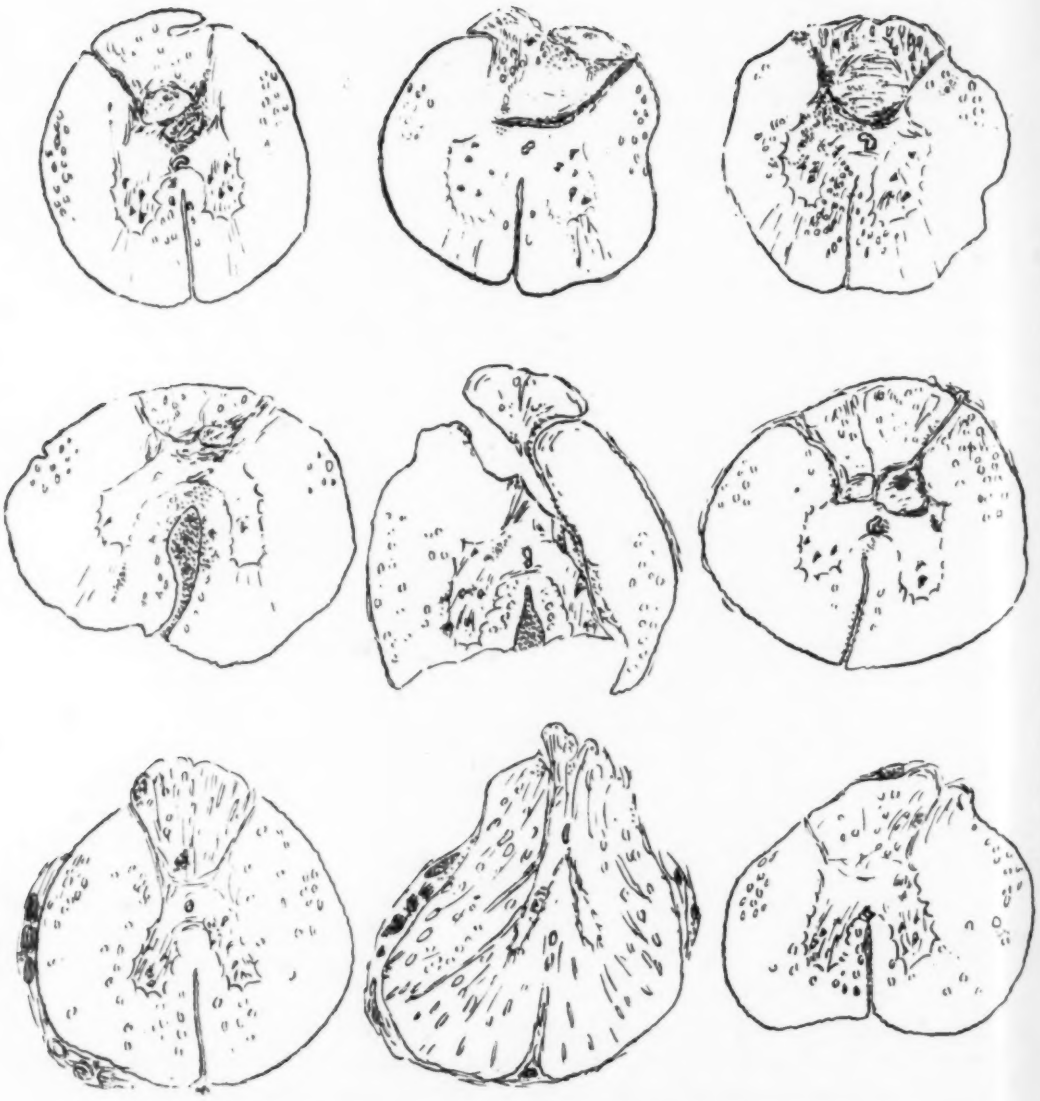

Fig. 5.—Above, left to right: Section of cord, 0.5 cm. above lesion, through lesion and 0.5 cm. below lesion (Dog 4). Center: Section of cord, 0.5 cm. above lesion, through lesion and 0.5 cm. below lesion (Dog 5). Below: Section of cord, 0.5 cm. above lesion, through lesion and 0.5 cm. below lesion (Dog 6).

in this specific region of the cord above and below the lesion with which we are particularly concerned in this paper. Attention is called to the fact that, in partial lesions of the cord, the pulp formed at the site of lesion is small in quantity and does not invade the cord above and below for any great distance, though the principle of the movement is the same as in complete lesions.

Dog 6 was subjected to a treatment slightly different from that of the other dogs of this group. It will be noted that the dura was incised over the site of the lesion immediately following crushing of the cord. Examination of these sections will show that, through the lesion, the entire mass of the cord seems to have flooded toward the point of released pressure. All of the different constituents of the cord seem to have been swept into the line of the nick in the dura and the defect in the pia by the rush of a current in a manner very much as débris is arranged by a flood passing through a break in a levee. The vacuoles of the edematous areas have their long axes toward the nick, and the anterior gray horns seems to have been totally disintegrated at this level by the current. Above and below the lesion, the dorsal columns alone show the effect of the current, though the edema is just as marked. There appears to be less hemorrhage in all sections in this cord.

A. R. Allen,[1] in his tentative conclusion, advised, in all cases of spinal fracture with symptoms of a transverse lesion, early laminectomy and medial longitudinal incision, in order to drain the injured tissues of products of edema and hemorrhage. His subsequent histopathologic findings do not indicate that his incision is without its dangers. An examination of the sections of Dog 6, as given above, will illustrate that, from a pathologic point of view, such sudden relief of intrapial pressure would cause untold damage to the cord at the site of lesion without the relief of the edema. In the first place, a comparison of the amount of edema in Dog 6, which lived thirty-two hours, and in Dog 4, which lived only eight hours, will show that the edema is considerably more marked in the former dog. If the relief of the pressure is expected to relieve or lessen edema formation, this should not have been the case.

In the second place, such an incision would not open and drain the lateral columns of the cords, where much of the edema is situated. In the third place, a too sudden relief of the pressure causes the disintegration of the healthy or reasonably healthy cord substance, as the sections show. In the fourth place, the anterior spinal artery or its

1. Allen, A. R.: Surgery of Experimental Lesion of Spinal Cord Equivalent to Crush Injury of Fracture Dislocation of Spinal Column, J. A. M. A. **57**:878 (Sept. 9) 1911.

Fig. 6.—Above, left to right: Section of cord, 2 cm. above lesion, through lesion and 2 cm. below lesion (Dog 1). Center: Section of cord, 3 cm. above lesion, 1.5 cm. above lesion and immediately above lesion. Below: Section of cord through lesion and 2 cm. below lesion (Dog 2).

anteromedian branch is in considerable danger in this incision. One factor in favor of the incision seems to be the less amount of hemorrhage present. Finally, the presence of vacuoles in the lateral aspect of the human cord (Figs. 17, 18 and 19), in which no vital process has been active, would indicate that perhaps it is the mechanical movement of lymph in these localities which gives the appearance of edema formation. This latter point requires further investigation. Hence, it would appear that operative interference of any sort is uncalled for, being useless in complete lesions and harmful in partial lesions, none of the expected results being accomplished, from a pathologic standpoint at least, in spite of the clinical results in Allen's dogs.

COMPLETE CORD CRUSHES

EXPERIMENT 5.—*Operation.*—Dog 1, a large female, July 22, 1922, under ether anesthesia, was subjected to a laminectomy in the dorsal region, with exposure of the cord and subsequent crushing of the cord completely through the dura, with the finger. After removal of the finger, it was noted that the cord was separated, and through the interval, spinal fluid flowed freely beneath the dura. After a moment, there seemed to be a return of blood and pulp to the area, and the gap was filled in with a dark mass. There was complete paralysis below the level of operation. The following day, the reflexes (plantar and tendon) were exaggerated; the sphincter and vaginal, active. The dog died on the morning of the third day immediately following catheterization. The spine was removed with the cord intact and placed in 10 per cent. formaldehyd. The animal lived forty-one hours.

Gross Pathology.—At the site of the lesion, the cord was reduced to a soft pulp, mixed with a fair amount of blood. This portion of the cord was about 1 cm. in length. Above and below the lesion, in the posterior central part of the cord, invasion by blood and pulp was evident for about 7 cm. above the lesion and for 4 cm. below. The area occupied by the pulp seemed to remain the same or to increase in diameter on passing above the lesion, and appeared to diminish in size as it passed down.

Microscopic Examination (Fig. 6, above).—Total destruction and pulp formation of the dorsal half of the cord, with marked hemorrhage in and around the pulp, was characteristic of a section through the lesion. Two cubic centimeters above the lesion, the central canal could not be located. There was marked invasion by pulp and blood into the posterior central part of the cord. The central part of the invading material was definitely separated from its surroundings. The posterior gray columns were considerably encroached on. Two cubic centimeters below, the invading blood and pulp were more sharply marked by a definite separation from fairly healthy cord substance about it.

EXPERIMENT 6.—*Operation.*—Dog 2, a small white male, July 22, 1922, under ether anesthesia, was subjected to laminectomy as previously performed. There was separation of the cord, and the results were as before. The following day all shock had passed away, with a marked paralysis of the lower half of the body. The reflexes were exaggerated, with very evident sphincteric reflexes present. The bladder was drained by catheter for three days, and after that time, the bowels and bladder acted automatically. In spite of care, the animal

developed bed sores of fairly severe character. At the end of two weeks, the condition of the dog became so bad that he was killed by etherization, the spine being removed with the cord intact. The animal lived fourteen days.

Gross Pathology (Fig. 1).—At the site of the lesion, the dura was adherent to the ventral aspect of the cord, the latter being reduced to half its normal size and of a porous nature. Six cubic centimeters above the lesion, the cord appeared normal. There was a cavity formation involving the posterior central part of the cord, extending for 4 cm. above the lesion and 3 cm. below.

Microscopic Examination (Fig. 6, below).—The central canal seems intact at all levels. The cavity begins immediately above and below the lesion, not as a single definite cavity but as irregular spaces with many smaller channels leading into the single, more cylindrical cavity. The area of the cord involved in the cavity here is much greater, occupying most of the dorsal half of the cord. Two cubic centimeters below the lesion, the cord appears very much as it does the same distance above, except that it encroaches on the dorsal columns almost as far as the pia mater. There is a marked vacuolation through the dorsal and lateral white columns extending the distance of the cavity formation.

EXPERIMENT 7.—*Operation.*—Dog 3, a small white female, was operated on, July 15, 1922, under ether anesthesia, an attempt being made to crush the cord by the use of heavy forceps, without laminectomy. The dog was not paralyzed by the operation, and after several days of uncertain activity of the hind legs, the animal became normal. The cord was probably not injured at all. Three months later, October 10, the cord was exposed by laminectomy and crushed as in Dogs 1 and 2. The dog was allowed to live long enough after coming out of the anesthesia to determine whether paralysis was present, and was then killed with ether, the spine and cord being treated as before. The animal lived one hour.

Gross Pathology.—The cord was split longitudinally at the site of the lesion. There was a slight amount of hemorrhage distributed above and below the lesion, of irregular nature. The pia mater was apparently ruptured just above the site of the lesion. The section of cord subjected to attempted crushing three months before was normal.

Microscopic Examination (Fig. 7, above).—One cubic centimeter above the lesion, the pia was ruptured at the side of the entering dorsal nerve roots. There was an anteroposterior split through the entire cord at this level, and slight hemorrhage along this line. One cubic centimeter below, there was only a marked hemorrhage involving the horns and central gray matter. There was no evidence of edema. Three cubic centimeters below, there was only a subpial hemorrhage over the dorsal white columns.

EXPERIMENT 8.—*Operation.*—Dog 8, a small female, April 21, 1923, under ether anesthesia, was subjected to laminectomy as before, with exposure of cord and crushing with the broad end of a knife handle. A complete lesion was evident, with refilling of gap with bloody mass after an interval. The dog was swung in a muslin hammock. The following day, it was catheterized. Marked increase in reflexes, both tendon and response to the prick of pin on the sole of the paw, was shown. Mass reflex and elevation of the tail followed stimulation of the clitoris. The next two days, the dog did not eat and seemed weaker. On the morning of April 25, the dog died. The cord was removed as before. There was no evidence of sepsis. The animal lived four days after operation.

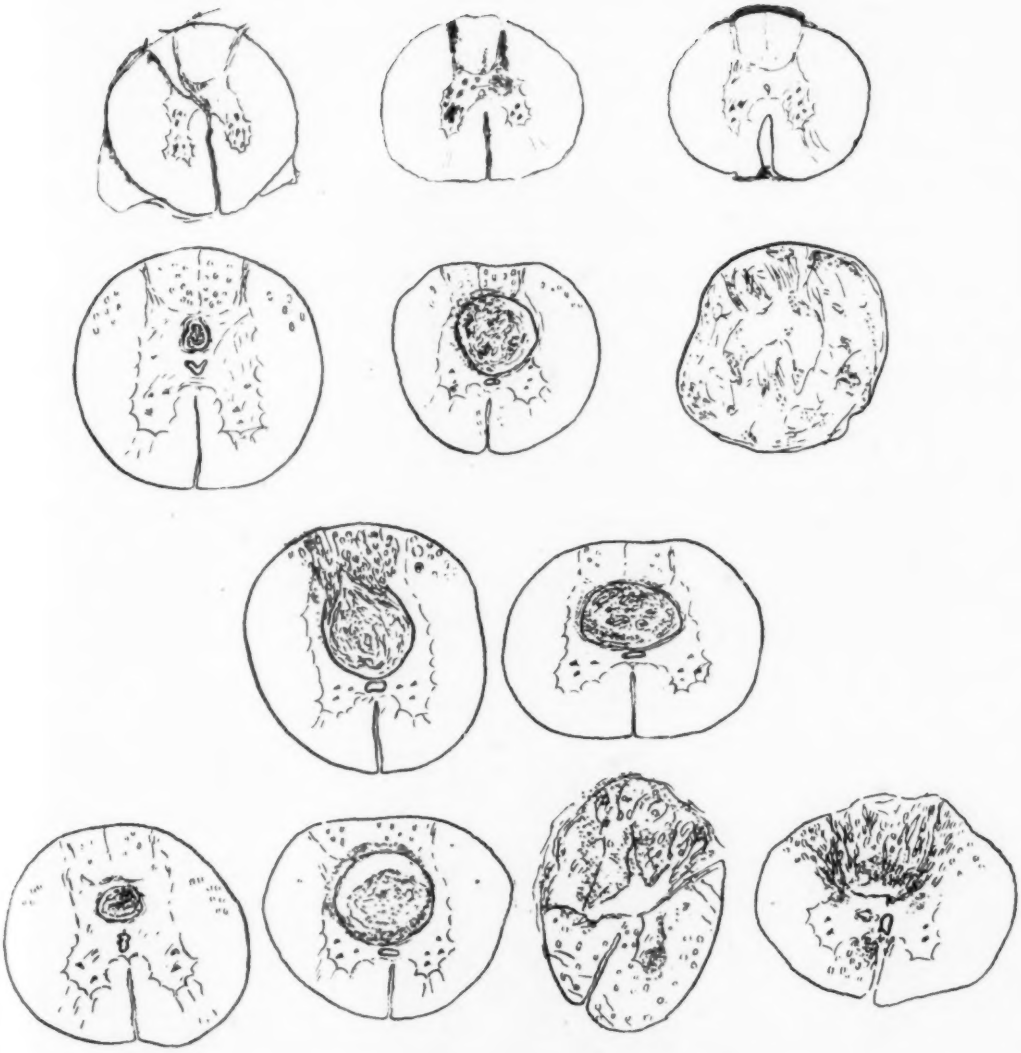

Fig. 7.—Reading, left to right, from top to bottom: Section of cord, 1 cm. above lesion, 1 cm. below lesion and 3 cm. below lesion (Dog 3). Section of cord, 2 cm. above, 1 cm. above and through lesion. Section of cord, 1 cm. below and 2 cm. below lesion (Dog 8). Section of cord, 2 cm. above, 1.5 cm. above, through lesion and 0.5 cm. below (Dog 9).

Gross Pathology (Fig. 8).—At the site of the lesion, the cord was reduced to blood and pulp. Some prominence of the dorsal white columns was noted, and subpial hemorrhage extending principally up the cord from the site of injury. A tube of pulp and hemorrhage extended up the cord for a distance of 4 cm. and down 3 cm., occupying the posterior central aspect of the cord.

Microscopic Examination (Fig. 7, five center sections).—Through the lesion, the entire cord mass is reduced to an unrecognizable, pulpy consistency with a

Fig. 8 (Dog. 8).—Gross appearance of cord at various levels.

fair amount of hemorrhage into it. Two cubic centimeters above, there was a small area of pulp invasion just dorsal to the central canal, with very little hemorrhage. One cubic centimeter above, the area of invasion was just dorsal to the central canal, occupying about one third the diameter of the cord. The central part of the area showed separation from the walls of the space occupied, with many large granular glia cells, identical with those described by Gordon

Holmes in this region. Blood cells were most numerous in the periphery. One cubic centimeter below, the area was the same as 1 cm. above, with the exception that the dorsal white columns were more involved and were the seat of marked edema. Two cubic centimeters below, the area of involvement was almost identical with the area 1 cm. above.

EXPERIMENT 9.—*Operation.*—Dog 9, a medium sized female, was operated on, April 21, 1923, under ether anesthesia, laminectomy being performed as in Experiment 8. The cord was crushed with the finger in this case; and results were similar, with separation of the ends of the cord and refilling with blood and pulp as before. The clinical history of this dog was practically the same as that of Dog 8, except that Dog 9 became entangled in her hammock during the night preceding April 25, and was hanged, death resulting. The cord and spine were removed as before. The animal lived three and one half days after operation.

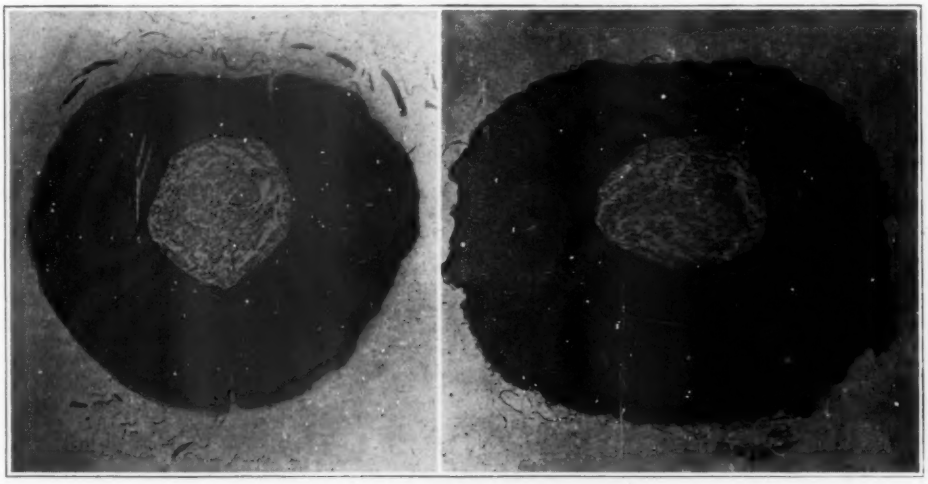

Fig. 9 (Dog 8).—Left, microscopic section through cord, 1 cm. above lesion; right, section 2 cm. below lesion. The pulp is in the process of absorption. (Compare with Figure 10.)

Gross Pathology.—This was identical with that in the case of Dog 8, with the exception that the dorsal white columns were more seriously encroached on for a short distance below the lesion. The pulp and blood advanced approximately the same distance as in the previous case.

Microscopic Examination (Fig. 7, below).—Through the lesion, the cord was reduced to a bloody and pulpy mass, with no evidence of the former architecture, with the exception of the location of the anteromedian fissure. Two cubic centimeters above the lesion, there was a small area of pulp invasion, with some blood cells just posterior to the central canal, which remained intact. The central part of the area was undergoing liquefaction, and the periphery of the mass of pulp had separated from a definitely outlined wall of cord containing excess of glial tissue. One and five-tenths cubic centimeters above the lesion, the area was about one third the diameter of the cord. There was a marked collection of blood cells in the periphery of the area. One cubic

centimeter below, the location and extent of the invading pulp was about the same as it was 1.5 cm. above. Five-tenths cubic centimeter below, apparently the entire dorsal columns were destroyed by pulp invasion in the ventral part and edematous infiltration in the dorsal part. The same was true of the portion 1.5 cm. below, with some hemorrhage. In each of the sections below, the dorsal parts of the lateral columns were also edematous.

In all of the dogs, complete crushing of the cord was performed by pressure with the finger, with the exception of Dog 8, in which the broad handle of a knife was used. A separation of the ends of the crushed cord for perhaps 0.5 cm. with subsequent filling in of the gap with bloody pulp was observed in each case. In all dogs, complete paralysis occurred below the site of lesion, bladder and bowel evacua-

Fig. 10 (Dog 1).—Section of cord, 1 cm. below lesion.

tions becoming automatic after three days in all subjects living at least that length of time. The reflexes, both patellar and plantar, were exaggerated. In the case of the females, mass reflexes and elevation of tail were evident on stimulation of the clitoris.

The gross appearance of the cords indicates that the cord substance at the site of the lesion was reduced to a hemorrhage pulp in each instance. Microscopic examination of sections through the lesion revealed little if any normal cord where the section went directly through the lesion. This pulp was evidently under considerable pressure since sufficient pressure was used to approximate the finger and the body of the vertebra. In every case, the sections above and below the lesion for the distance of several centimeters show the presence of

cord pulp and blood in a definite location in the posterior central part of the cord. When the dog lived two weeks, a cavity occupied the same relative position and extent in the cord. We now have certain facts upon which we may base our consideration of the mechanical factors involved in such crushing of the cord.

The first factor is local force or pressure. This is fundamentally the same whether caused by the finger, as in the experimental lesion, or by the apposition of the vertebral body and posterior arch of the adjoining vertebra, as occurs clinically in fracture dislocations. Compressibility is the second factor concerned. The cord is a compressible substance enclosed within a fairly firm, slightly elastic canal of pia mater. There is a limit to the compressibility of all substances; so in the cord there is a limit beyond which the cord substance is reduced to a pulp.

The question then arises as to the expenditure of the pressure which has been necessary to crush the cord in this manner. In the case

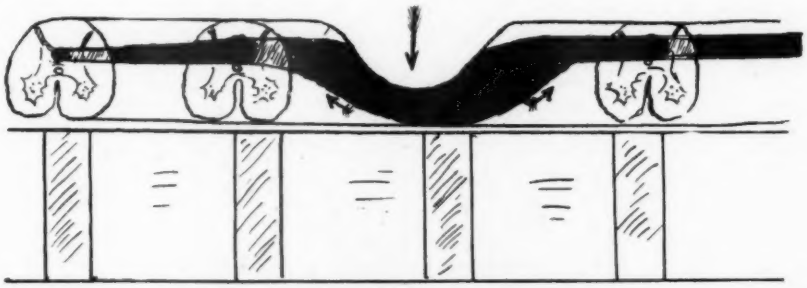

Fig. 11.—Diagrammatic representation of spinal cord showing pulping of cord at level of lesion and distribution of this pulp above and below the lesion as indicated in black (reconstructed from cords of Dogs 1, 8 and 9).

of Dog 3, the pressure was evidently relieved by the rupturing of the pia mater. In the case of Dogs 1, 8 and 9, a different and very characteristic phenomenon occurred. Sections which were made at considerable distance above and below the site of lesion showed that cord pulp and blood, evidently from the site of injury, have made their way up and down the cord, the pia mater in all of these cases remaining intact. Thus, the intrapial pressure originating in the crushed portion in these cases is transferred to the segments of the cord above and below, owing to the entrance of the pulp into these segments; and as it tracks up and down the cord, its force is thus expended.

The portion of the cord usually chosen by the invading pulp mass is the central gray matter dorsal to the central canal, rarely involving the central canal, and the ventral portion of the dorsal white columns. It corresponds very closely to the area of the cord described by Buzzard and Greenfield as *locus minoris resistentiae* (the place of least resist-

ance), principally because of its poor blood supply. They speak of lymph tracking up and down the cord through this area from the site of lesion. Gordon Holmes also speaks of this. However, poor nutrition in itself would not account for the constancy with which the cord pulp (and not lymph), in its effort to adjust the intrapial pressure, seeks this specific region of the cord. It may be reasonably accounted for by a consideration of the anatomic arrangement of the cord constituents. Reference to Figure 11, which is a diagrammatic representation of the cord of Dogs 1, 8 and 9 will show the pulp formation at the site of lesion due to local pressure applied in the direction of the arrow. The pia remained intact in all of these cases; hence, the pulp must go somewhere, and it necessarily tracks up and down the cord, as indicated

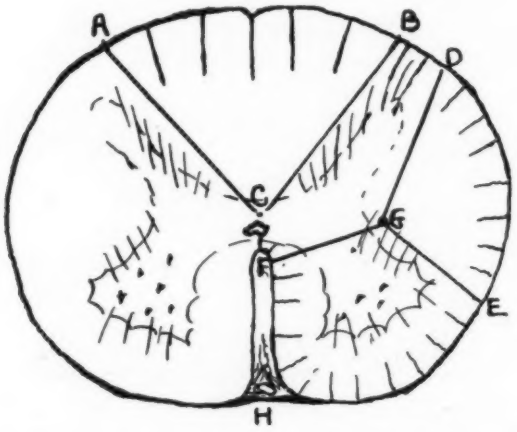

Fig. 12.—Diagrammatic section through cord, showing how any increase in intrapial pressure tends to bind the cord constituents anterior and lateral to the lines *AC* and *BC* more firmly together, thus causing pressure to be diverted toward triangle *ACB*. Fibers are shown entering and leaving the gray horns which serve to strengthen these areas.

in black. Whereas the pulp at first is forced against a fairly large area of cord surface, it is noticed that soon the paths taken by the advancing pulp begin to converge toward the ventral part of the dorsal white columns and the central gray matter, and this site is maintained until the pressure is expended.

What counteracting forces are at work which oppose the invasion of the pulp at all parts of the cord except the location always chosen? In the first place, the cord is fairly firmly bound in a tube of pia mater, which, however, is somewhat weaker, comparatively speaking, in the dog than in man. This pia surrounds the cord very intimately, and a fold of it extends up into the anteromedian fissure. Extending from

the pia are many blood vessels, ensheathed in pial investments, which penetrate some distance into the cord and serve to bind a zone of peripheral white matter to the deep aspect of the pia.

Suppose, now, that the intrapial pressure should be increased by the attempt of blood and pulp, formed at a lesion a segment below, to invade this part of the cord, as pictured in Figure 12. The first result would be an increased tension of the pia. At first thought, it seems that the anteromedian fissure would spread and thus relieve the pressure; but it must be remembered that the linea splendens serves to bind

Fig. 13.—Diagram showing vascular supply of the cord. Each vessel carries with it a pial investment which interlaces with the cord constituents, serving to bind them more closely together. The area of poor blood supply is shaded.

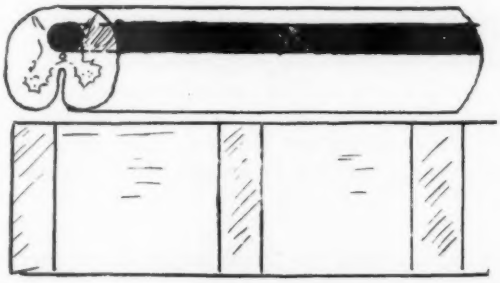

Fig. 14.—Diagram of formaldehyd-hardened human cord in the thoracic region, showing in black the uniformity of the cavity remaining after the ventral part of the dorsal white columns had been stripped grossly with the forceps from above downward or vice versa.

the walls of the lower end of the fissure together. Thus, a tense pia acting from point *F* as a point of attachment, then swinging about *H* as a pulley, and extending back to *A* and *B*, which are near the entrance of the posterior nerve roots, would tend to isolate the lateral and anterior parts of the cord on each side, as indicated by the lines *AC* and *BC*, so far as pressure is concerned. Therefore, the cord constituents would be more closely massed together anterior and lateral to

the two lines indicated after the first increase of intrapial pressure due to the invading pulp had occurred, and would thus offer more resistance to further invasion.

Other conditions exist which add to the resistance of this anterolateral area against invasion. One of the most important factors was alluded to previously. A glance at Figure 13 will give some idea of the blood supply to the cord. Each blood vessel carries with it into the cord substance a sheath derived from the pia mater. These vessels all converge toward the point *G* in Figure 12. They pass in from points *D*, *E* and *F*, and at many points between these places, converging like the spokes of a wheel. These serve to bind the constituents of the anterolateral part of the cord together. Also, it will be remembered that extending from the anterior gray horns are the anterior nerve roots, passing through the white matter to the surface of the cord; while passing into the lateral aspect of the anterior horns are fibers from the pyramidal pathway, and many other descending fibers. The posterior horns are

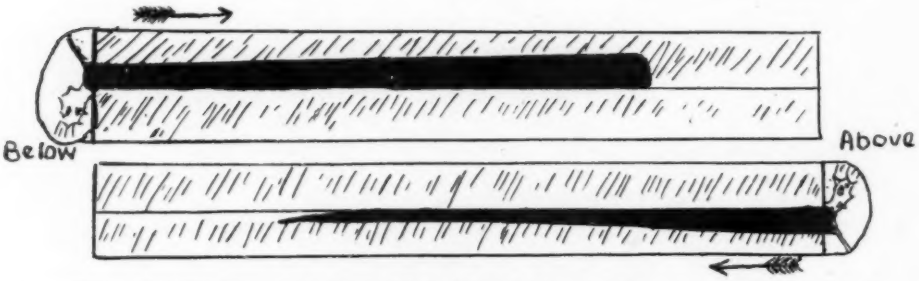

Fig. 15.—Diagram of formaldehyd-hardened human cord from cervical region showing variations in size of cavity remaining after the ventral part of the dorsal white columns had been stripped with forceps from below upward (above) and from above downward (below). This accounts for the fact that the area involved in pulp invasion is greater above than below the lesion in cervical crushes.

entered by fibers and collaterals from the posterior nerve roots. Thus, we see that the anterolateral aspect of the cord is rather firmly meshed together.

A consideration of the state of affairs existing within the triangle *ABC* brings to our attention the following facts. In the first place, the dorsal part of this area for a certain depth is bound to the deep aspect of pia by blood vessels and their pial sheaths, just as in the other parts of the cord. The blood vessels, however, are small and do not penetrate deeply into the cord. The posterior median septum is composed of glia only except where a median vessel carries in with it a pial investment. A glance at Figure 13 will show that the area shaded is devoid of any large vessels. In the second place the ventral part of the dorsal columns is made up of fasciculi proprii and, to a much less degree,

Fig. 16.—Above: High power drawing of area of cord dorsal to and including the central canal. The animal (Dog 1) lived forty hours. The pulp mass is separated from the cord by an interval. Center: Corresponding area of cord of Dog 8, showing decreased density of pulp. Accumulation of blood cells around periphery of pulp and increased number of granule glial cells. The animal lived four days. Below: Portion of wall of cavity with granule and vacuolated glial cells in the cavity, in the walls and in the central canal (Dog 2).

of a few ascending and descending association fibers, all of which have a longitudinal course. This area of white matter is not bound to the surrounding cord by blood vessels or pia, owing to its distance from the periphery of the cord. Collaterals leave this column, it is true, but they first pass laterally and arch toward the anterior horns of gray matter, thus leaving the gray matter just posterior to the central canal practically unattached to the white matter dorsal to it.

Therefore, we may conclude that, from an anatomic standpoint, the ventral part of the triangle *ABC* is the portion of the cord which will offer least resistance to the invasion of pulp. In other words, the blood and pulp invading a segment of the cord at first is directed against the whole face of the cord, but at once meets resistance in certain localities which, on account of the structural arrangement of the constituents, tends to divert it toward areas which do not have the benefit of this arrangement. So, in this manner, the constant location of the invading pulp and blood may be explained.

As the pulp invades the cord above and below the lesion under pressure, it pushes aside the white fibers which are poorly bound together; separates them from their neighbors, and cuts off their blood supply by tearing through their capillary walls, which accounts for the hemorrhage above and below the actual site of lesion in the region of the periphery of the column of pulp. Thus, the pulp not only invades but also destroys the blood supply of the area affected, either by rupturing the vessels or compressing their walls; and, furthermore, by pressure causes destruction of the nerve fibers pushed aside or included within its boundaries. It has been pointed out that in none of these cases is there a massive hemorrhage.

A study of the sections above and below the lesion in the case of Dog 1, Figure 6, shows that the area involved in the pulp invasion is smaller and extends a shorter distance below the lesion than above. Also in Dog 8, Figure 5, it will be noticed that while the area 3 cm. below the lesion is a mere pin point, the area above the lesion at a similar distance is reduced very little in size. An attempt was made to account for this difference, since the same state of affairs seemed to exist in several of the human cords in our collection. The area of invasion being the ventral part of the dorsal white columns, the fibers involved are the fasciculi proprii of the region of the cord. In the cervical region, where great numbers of the afferent fibers enter the cord, coming principally from the upper extremities, the fibers of the fasiculi proprii are also increased in number, particularly the ascending fibers. The descending fibers are pressed on dorsally by the ascending fibers that have entered at the segment below, and at the same time these descending fibers are diminishing in number, owing to their entrance into the gray matter.

The reverse is also true, i. e., the ascending fibers, though they too are diminishing in number, still are pushed dorsally as they pass up the cord, owing to the presence ventrally of the descending fibers from the segment above. In the thoracic region, though the number of entering fibers is greatly reduced, there is still a slight tendency of the area involved above to be slightly larger, owing possibly to the proximity of the cervical enlargement above.

An effort was made to confirm this grossly. A portion of cervical cord, fixed in formaldehyd, was split in halves by an incision through the anteromedian fissure and posteromedian septum. A portion of the ventral part of the dorsal white columns was then taken in the forceps, and, when it was stripped from above downward, the cavity thus formed decreased in caliber from above downward, forming an apex about two segments below. This is illustrated in Figure 15. The same diagram shows the result of stripping a similar area from below upward, the cavity thus formed remaining approximately the same in diameter, and sometimes increasing slightly. Thus, pulp entering the area of least resistance and passing down the cord follows along the course of these fibers; and, thus advancing, it is caused to take a path that is gradually decreasing in diameter, being pressed toward the center of the cord until its force is expended. On the other hand, when the pulp is forced up, its area of involvement, following the course of ascending fibers, maintains a constant diameter, sometimes increasing and sometimes decreasing, as the force diminishes.

When a portion of the thoracic cord was treated in a similar manner, the result was a cavity of approximately the same diameter, regardless of the direction of stripping the fibers. Figure 14 is illustrative of this fact in the thoracic region. Hence, one would expect that a lesion occurring in the thoracic region would cause a column of pulp to invade the neighboring segments, which would have about the same diameter when traced in either direction, becoming narrower only near the extremities, when the force is almost exhausted.

LATE CHANGES IN THE CORD

Gordon Holmes[2] describes very accurately the secondary changes in the cord as a result of war injuries. He describes the cavities very minutely, and the description which he gives holds absolutely for the condition which was found in our experimental lesions.

A comparison of the cord sections of Dog 2, Figure 1, and of Dog 8, Figure 8, will serve to illustrate the changes which take place above and below the site of the lesion in the injured cord. Dog 2, it

2. Holmes, Gordon: The Goulstonian Lectures on Spinal Injuries of Warfare, Brit. M. J. **2**:769, 815, 855, 1915.

will be remembered, lived two weeks; whereas, Dog 8 lived but four days. The striking feature in a comparison of these cords is the fact that the cavity in the former cord is identical in position with the invading pulp area in the latter. Thus, the condition of Dog 2, ten days before its death, was probably identical with the state of the cord of Dog 8 at the time of its death. In other words, a study of these cords would indicate that, following the invasion by the blood and

Fig. 17.—A human cord which was subjected to postmortem pressure. Arrow points to lesion.

pulp up and down the cord, with the pushing aside of white matter, and the isolation of some white matter with its destruction either by pressure or by rupturing of, or pressure on, walls of blood vessels in the area invaded, a process of absorption sets in, with the ultimate liquefaction and removal of all invading blood and pulp and destroyed cord substance.

Figure 16 shows the progressive changes which take place in the process of cavity formation. The drawings were made to scale by use of microprojection apparatus, and each represents the same relative position in the cord, i. e., just posterior to the central canal and including a portion of the cord in the area immediately adjacent to the invaded area, and some of the invaded area in each case. In the dog that lived forty hours, the pulp mass is slightly separated from the adjacent cord, and there are found a few glial cells of the ameboid and granular type in the débris as well as in the cord adjacent. In the dog that lived four days, the pulp material was not so dense, and the number of glial cells was increased both in the débris and in the walls of the peripheral matter. In the dog that lived two weeks, it will be noted that only a liquid remained in the area formerly occupied by the pulp, and the turbidity of this liquid was dependent on the vacuolated glial cells which it contained. That a glial reaction had occurred was evident from the thickening of the walls of the cavity.

The result is that cavity formation is brought about in that part of the cord corresponding to the area involved in the invasion by the pulp. An examination of the section immediately above the lesion (compare this section in Figure 6) would indicate that this area of the cord, owing to the irregularity of the cavity and its cavernous type, was the site which, during the passage of the pulp, represented the area of deflection. Thus, the pulp, in ascending and at the same time shifting gradually toward the area of least resistance, tunnelled the cord substance in this area which, being followed by liquefaction, left many irregular channels, all leading into the main cavity above. Hence, this cord adds to the evidence in favor of the course of the pulp being gradually diverted to the posterocentral area of the cord.

HUMAN CORD

A human cord was obtained at necropsy, which was performed fourteen hours after death. Laminectomy was performed in the dorsal region and about 5 inches of cord in dura was resected. It was then placed on a firm surface, and pressure was made with the finger in the dorsal region of the cord. As the pressure was being made, the segments of the cord above and below the lesion were noticed to bulge; and after the finger was removed, the cord remained ribbonlike but not without some return of pulp to the area on release of pressure. The dura was then slit up, and the whole placed in 10 per cent. formaldehyd to harden.

The gross cord appeared very like the specimens from cases of actual fracture of the spine which we have in our collection. Figure 17 shows a photograph of this cord. It is flattened and ribbonlike

at the site of lesion. Sections above and below the lesion show the presence of pulp matter in the posterocentral part of the cord.

Microscopic sections appear in Figures 18 and 19. Their great similarity to the dog cords should be noted. Two cubic millimeters above the lesion there is a practically normal cord, with the exception

Fig. 18.—Section of cord shown in Figure 17, 2 cm. above the lesion. The pulp has definitely invaded and pushed aside the dorsal columns. Arrow points to high power photograph of area outlined showing lymph spaces, which suggests that such a condition may be mechanical rather than vital.

of the dorsal columns. A mass of pulp occupies the ventral part of the dorsal white columns, being present to one side of the midline. The white column of the other side is pushed aside and compressed. There

are a few white fibers isolated and included in the pulp-invaded area. The pulp mass is laminated. The dorsal gray horn nearest the pulp mass is bowed out and compressed, with its concavity toward the pulp mass. The anterior horns are normal. The pia is everywhere intact, and the anteromedian fissure has its normal relations. The central canal has not been destroyed, though its walls have been approximated by the pressure. The presence of many swollen nerve sheaths in lateral white columns, giving them a vacuolated appearance, raises the question as to whether this condition is a vital or a mechanical one, and requires further investigation. One cubic millimeter above the lesion, the area occupied by the mass of pulp is much greater, involving nearly all of

Fig. 19.—Section of cord shown in Figure 17, 1 cm. below the lesion. The area of pulp invasion is greater, and in the center may be seen several large pyramidal and oval cells having the appearance of cells of anterior horn and nucleus dorsalis.

the dorsal white columns except a small zone adjoining the pia. The cord around the mass has been pushed aside and shows signs of compression. The center of the pulp mass shows a few large cells which are not unlike anterior horn cells and some others which are very evidently cells from the nucleus dorsalis. No section was made through the lesion, for here the cord was reduced to a mere empty tube of pia mater containing some pulp material which returned to the area after the pressure was released. One cubic millimeter below the lesion, the state of affairs is very similar to that existing 1 cm. above.

It seems that this experiment with the human cord proves beyond a doubt the pulp invasion theory. When the cord was subjected to pressure, no doubt what actually occurs in fracture dislocations which crush the cord was reproduced. The segments above and below the site of pressure were seen to bulge, owing to the slight elasticity of the pia. The pressure was released and the cord remained flattened, though some of the pulp material returned to the area. Then the cord was sectioned, and the pulp material was found above and below the lesion in the location observed in all of our dog experiments and our actual

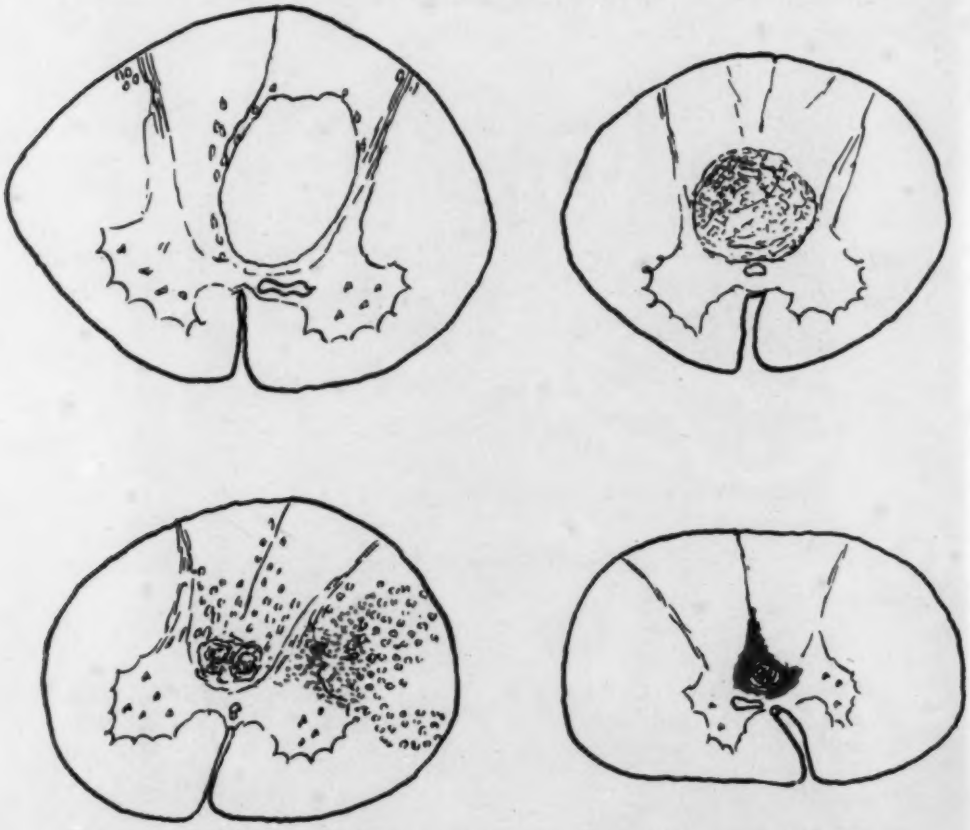

Fig. 20.—Sections of cords from actual cases of fracture dislocation for comparison with experimental lesions. Above, left: Section of cord below lesion of second vertebra. The patient lived three weeks. Right: Section of human cord, 1 inch (2.5 cm.) below lesion. The fracture included the seventh cervical vertebra and extended to the first thoracic vertebra (patient lived forty-eight hours). Below, left: Section of human cord above lesion in fracture of the sixth and seventh cervical vertebrae (patient lived six days). Right: Section of human cord, 1 cm. above lesion of fifth and sixth cervical vertebrae (patient lived one day).

cases as well. The condition found also corresponds to the pictures and descriptions which Gordon Holmes gives in his article on war injuries.[2]

For comparison, we have included four sections (Fig. 20) taken from cases of actual cord crushes due to fracture dislocation of the spine. These should be compared with the cords of dogs, with particular reference to the position and similarity of the invading pulp and blood or of the cavity. Thus, there is a striking likeness in the case of the section (1.5 cm. above the lesion) of the cord of Dog 2, Figure 6, and the section above the lesion from the case illustrated above, left, in Figure 20. Sections of cords from Dogs 1, 8 and 9 compare very favorably with the remaining (human) cases in Figure 20. Another point which should be called to the attention is the still further similarity when one considers the period of time elapsing between crush and death.

Experimental lesions as we have produced them in dogs and in human cords obtained at necropsy are comparable to actual cord lesions in man in all respects, but more especially as regards the mechanical factors as we have discussed them, and the early and late pathologic pictures. The progressive vital changes in the area of the cord involved are strikingly similar. Hence, our conclusions may be applied to actual cases of cord crush.

CONCLUSIONS

1. In partial lesions of the cord, there is usually not sufficient pressure to convert the cord at the site of lesion completely to pulp, and what little pulp is formed is not under sufficient pressure to track very far up and down the cord. That part of the adjacent cord which is invaded, however, is usually an area similar to that invaded in complete lesions, and the principles involved are the same.

2. Edema and hemorrhage are factors to be dealt with in partial lesions and concussions. Massive hemorrhages do not occur as a rule, and small scattered hemorrhages are most often observed. These are probably not extensive enough to produce serious injury, of themselves. Edema comes on within eight hours and attacks the dorsal white columns principally, but it is frequently quite marked in the lateral and anterior columns as well. Time is a factor, since edema seems more marked in proportion to the length of time the dog lives. A marked intrapial pressure is developed as the result of the edema. . This becomes more evident when the dura and pia are incised and this pressure is released. Judging from the case in which the dura was nicked, it seems that operative procedure would cause a further destruction of the cord substance without the relief of the edema in areas of the cord often affected. The release of the pressure seems to have no effect in checking edema formation.

3. In complete lesions of the cord, the cord at the site of the lesion is reduced to a pulp and blood mixture, and the ends of the cord separate for a short interval. The pulp is forced into the segments above and below the lesion and causes an increased intrapial pressure, which is released in one of two ways: either the pia ruptures or the pulp tracks up and down the cord until the intrapial pressure is relieved. After an interval, in cases in which the pia remains intact and the local pressure is relieved, a bloody mass returns and fills the gap between the separated ends. If local pressure is maintained, as would be the case in an uncorrected fracture dislocation, no return of pulp would be possible.

4. The area of the cord involved in complete lesions is the area of least resistance, located in the ventral part of the dorsal white columns and that part of the central gray matter dorsal to the central canal. This locality is chosen because of the weaker anatomic structure of this area as compared with other areas.

5. In complete lesions, the area of cord involved in the pulp invasion tends to be larger above the level of the injury in the lower cervical and upper dorsal regions, and consequently more damage results in such regions. This is probably true also in the region of the lumbar enlargement.

6. Liquefaction of the pulp and the area of the cord involved in the débris in complete lesions sets in after forty-eight hours; is progressing rapidly at the end of four days, and is completed within two weeks. Thus, the syringomyelic cavity and symptoms above the level of the lesion and cavity below in many old cases of fracture of the spine are accounted for. The process is brought about by the rupture of or pressure on blood vessels supplying the involved area, and the pressure on the included nervous tissues which are pushed aside. The presence of an increasing number of ameboid and granule glial cells in this area suggests their phagocytic function.

PROGNOSIS AND TREATMENT OF FRACTURES OF THE LEG AND ANKLE*

END-RESULTS IN ONE HUNDRED PATIENTS

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Prognosis is defined as the art of foretelling the course and termination of a disease. In no case can one give any accurate prognosis without knowing from his own experience or from that of others what have been the course and termination of similar cases. Hence arises the importance of studying end-results as well as the clinical course of the disease.

It was shown in the report on fractures of the tibia and fibula presented to this association in 1921 [1] that among a total of 914 such fractures analyzed, good function was secured in 71 per cent. of cases, moderate function in 20 per cent. and bad function in 9 per cent. (Table 10); that the average period of disability in simple fractures was four months for ankle fractures and 4.7 months for fractures of the leg proper; while in compound fractures the average period of disability was five and seven-tenths months for the ankle fractures, and seven months for those of the leg (Table 12). It was further noted that these investigations merely pointed the way for further improvement in our means of treating fractures of the tibia and fibula; and that no surgeon having such fractures under his care should rest satisfied until he could publish a series of end-results which in the aggregate would be superior to those therewith reported, since these were merely the average.

It was with this in mind that the present investigation was undertaken. We have compiled accurate records of the end-results in 100 of 152 fractures of the leg and ankle treated in recent years in the service to which we are attached at the Episcopal Hospital, Philadelphia. With few exceptions, the patients have been personally examined by us or by Dr. I. M. Boykin. In the other cases, accurate reports have been secured by letter or by interviews with the social service workers of the hospital. Thirteen of these 152 cases were considered too recent for inclusion in a report of "end-results"; so that we have traced 100 of 139 cases, or 72 per cent. of the entire number treated (Table 1).

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* Read at a meeting of the American Surgical Association, June 2, 1923.

1. Ashhurst, A. P. C.: Tr. Am. Surg. A. **39**:528, 1921.

TABLE 1.—*Sites of All Fractures*

	Total	Nonoperative	Operative*
Fibula, shaft	5	5	..
Tibia, shaft, above middle	4	4	..
Tibia, shaft, below middle	16	15	1
Tibia and fibula, shafts, above middle	9	9	..
Tibia and fibula, shafts, below middle	22	14	8
Ankle A†	26	24	2
Ankle B	11	8	3
Ankle C	7	7	..
	100	86	14

* This does not include tenotomy of the Achilles tendon for reduction, two cases; Steinmann pin extension from os calcis, seven cases; nor one case of arthrotomy and suture of the knee for hemarthrosis.

† See footnote to Table 4.

TABLE 2.—*Results in All Cases*

		Functional Result		
Anatomic Result	Cases	Good	Moderate	Bad
Good	81	67	13	1
Moderate	17	5	12	0
Bad	2	0	1	1
	100	72	26	2

TABLE 3.—*Results in Leg Fractures*

	Cases		Functional Result				
			Good		Moderate		
Anatomic Result	Number	Per Cent.	Number	Per Cent.	Number	Per Cent.	Bad
Good	43	77	39	91	4	9	0
Moderate	12	21	4	33	8	66	0
Bad	1	2	0	..	1	100	0
	56	100	43	77	13	23	0

TABLE 4.—*Results in Ankle Cases**

Anatomic Result	Cases	Functional Result: Good	Moderate	Bad
Good	A21, B10, C 7 = 38 (86%)	A16, B 7, C 5 = 28 (74%)	A 4, B 3, C 2 = 9 (23%)	A 1, B 0, C 0 = 1 (2%)
Moderate	A 4, B 1, C 0 = 5 (11%)	A 0, B 1, C 0 = 1 (20%)	A 4, B 0, C 0 = 4 (80%)	A 0, B 0, C 0 = 0
Bad	A 1, B 0, C 0 = 1 (3%)	A 0, B 0, C 0 = 0	A 0, B 0, C 0 = 0	A 1, B 0, C 0 = 1(100%)
	44	29 (67%)	13 (30%)	2 (3%)

* A signifies fractures at ankle caused by external rotation of foot; B, those caused by fibular flexion (abduction), and C, those caused by tibial flexion (adduction) of foot (Ashhurst, A. P. C., and Bromer, R. S.: Classification and Mechanism of Fractures of the Leg Bones Involving the Ankle, Arch. Surg. 4 : 51 [Jan.] 1922).

The tables presented herewith are compiled in accordance with the plan of the Fracture Committee of this association, in its 1915 report. It is worth while recalling once again the definitions of this report: The anatomic result denotes the position assumed by the fragments of bone at the time of consolidation. In children, especially, a bad anatomic result in this sense may eventually prove to be a very good anatomic result, but in strict accord with our definition we have counted no anatomic result good unless at the time of consolidation there was present accurate anatomic reposition of the fragments. If such absolute anatomic reposition was not secured, the anatomic result has been recorded as "moderate," even if eventually the bone ends became rounded off so that no palpable deformity remained when the patient was last examined. Any gross anatomic deformity or any appreciable shortening (over 2 cm.) has been classed as a bad anatomic result (Tables 2, 3 and 4).

So also with regard to functional results, we have followed the Fracture Committee's criterion that a good functional result implies the absence of any disability whatever. If there is pain in damp weather, if the patient tires more easily, if after long standing or walking the foot or leg swells or if there is any limp, we have classed the functional result as moderate only, even if the patient has resumed his normal occupation and makes the same wages. Any real incapacity interfering with work has been classed as a bad functional result. We are happy to say such a result occurred only in two patients, both with fractures at the ankle. One of them, aged 40 years, did not come under our care for some weeks after her injury, when it was impossible to secure reduction. She has been unable to do any work since her accident eight years ago. The other patient, who also had an ankle fracture, was a woman, 43 years of age, who came under our care several days after injury, with great swelling and ecchymosis. As two attempts under a general anesthetic failed to secure reduction, she was operated on ten days after the accident, and though a good anatomic result was obtained, pain and disability persist to such an extent after two and one half years that the result must be considered bad.

We give in Table 5 a short summary of the cases in which a good functional result was not obtained. It may be noted that to all intents and purposes many of these patients have entirely satisfactory function; but as it is not perfect, we have classed the results with *moderate*, not *good*, in accordance with the definitions already adopted.

Of the 26 patients who recovered only moderate function, 17 had, and 9 had not, a lessening of endurance; 10 had, and 16 had not, pain at any time; 4 had, and 22 had not, a limp; 3 had, and 23 had not,

swelling; 3 had, and 23 had not, limitation of motion. Among our 100 end-results reported, shortening was noted in four:

Case 1.—A man, aged 57, had 1 cm. shortening, following a comminuted fracture treated by Steinmann nail traction. He was out of work nine months, and anatomic and functional results were both classed as moderate, since he had appreciable shortening and had a slight limp, and complained of pain in wet weather.

Case 2.—A man, aged 37, had 2 cm. shortening following a comminuted fracture of the upper ends of the tibia and fibula involving the knee joint, with marked hemarthrosis, for which arthrotomy was required. He was out of work three months, and anatomic and functional results were classed as moderate, as he limped in fast walking and had slightly less endurance, though he resumed his job at his former wages.

Case 3.—A man, aged 41, had 2 cm. shortening. He refused operation for a simple fracture of the shaft with marked displacement; was out of work fifteen weeks, and recovered perfect function.

Case 4.—A man, aged 48, with 2.5 cm. shortening, following a compound comminuted fracture of the shafts, which was inefficiently treated by extension through a Sinclair skate, was out of work ten months, and recovered with a bad anatomic result (shortening over 2 cm.) and only moderate function, as he had less endurance and made less wages, though working at the same job as before his injury. He had also a fracture of the patella of the other knee.

One patient had lengthening of 1 cm. in the fractured leg, following plating for irreducible displacement. He was out of work fourteen months (from no apparent cause), and secured a good anatomic and functional result. The plate was still in place when he was last seen, over six years after the injury. Bony union was secured in all the 152 cases treated. There were two or three cases in which union was delayed, especially in compound fractures, but no case of nonunion was seen. Nor did any case of peroneal paralysis occur.

It was pointed out in the 1921 report on fractures of the tibia and fibula that the reporters of many of the cases then analyzed had been less strict than the Committee in adhering to its definitions, as some reports then received classed as "good" anatomic results cases in which shortening of as much as 3 cm. was recorded; and as "good" functional results cases in which pain in damp weather persisted or there was evident, but not disabling, limitation of motion, and disability was partial, not entirely absent. In comparing the results there recorded, with those now presented (Table 10), this comparatively optimistic view afforded by the 1921 statistics should be kept in mind. We repeat that in our own cases, only those results have been classed as good functionally in which there was complete absence of any symptoms referable to the fracture. One patient was encountered who maintained that since he had broken his leg it was even better than before the accident.

TABLE 5.—*Patients Recovering Only Moderate Function*

Name, Age and Year Seen	Sex*	Fracture	Treatment	Anatomic Result	Time, Out of Work, Months	Disability	Same Position	Same Wages
Shaft Fractures								
M. C., 55, 1916	♀	Into knee joint	Fracture box 1 week; circular cast	Good	6	Knee flexes only to 90°; patient limps when tired	Yes	Yes
H. B., 65, 1921	♂	Upper third spiral	Fracture box 3 days; gypsum splints	Good	14 (law suit)	Less endurance after 2 years	Lower	Less
M. B., 57, 1922	♂	Lower third	Fracture box 4 days; then Steinmann pin	Moderate	9	Pain in wet weather; slight limp	Yes	Yes
E. C., 25,1920	♀	Lower half comminuted	Gypsum splints	Moderate	4	Pain in wet weather; less endurance after 3 years	Yes	Yes
T. D., 48, 1919	♂	Lower third compound comminuted	Sinclair skate	Bad	10	Less endurance; also had fractured patella of the other knee	Yes	Less
S. G., 32, 1916	♂	Upper half compound comminuted	Gypsum splints	Good	1	Knee flexes only to 70°; pain in wet weather	Yes	Yes
W. H., 34, 1916	♂	Lower half compound	Steinmann pin	Moderate	8	Less endurance	Lower	Less
A. H., 47, 1915	♀	Lower half compound comminuted (Figs. 11 to 13)	Steinmann pin	Moderate	?	Pain in wet weather after 5½ years	Yes	Yes
C. McK., 38, 1922	♂	Lower third compound comminuted	Steinmann pin	Good	6	Pain and swelling toward night after one year	Yes	Yes
J. M., 32, 1922	♂	Double fracture of tibia and fibula, compound (Fig. 18)	Smith clamps and Steinmann pin	Moderate	9	Less endurance; wore brace 1 year	Yes	Yes
J. P., 37, 1916	♂	Comminuted into knee	Arthrotomy for hemarthrosis; gypsum splints	Moderate	3	Slightly less endurance; limps in fast walking	Yes	Less
M. S., 16, 1921	♂	Lower third compound comminuted	Steinmann pin	Moderate	3	Pain in wet weather; less endurance	Yes	Yes
J. S., 60, 1920	♀	Lower half comminuted	Gypsum splint	Moderate	6	Pain, swelling less endurance	?	?
Ankle Fractures †								
P. B., 66, 1921	♀	Ankle A 2x	Fracture box 6 days; gypsum splints	Moderate	4	Swelling; less endurance (has generalized arthritis deformans)	Yes	Yes
H. C., 54, 1912	♂	Ankle A 2x	Fracture box 17 days; tenotomy, Achilles tendon and gypsum splints	Moderate	6	Less endurance; had former severe injury to both knees	Yes	Yes
P. D., 67, 1919	♂	Ankle A 2x	Fracture box 2 weeks; circular cast	Good	?	Pain at times; less endurance	Lower	One-half
J. O'M., 47, 1921	♂	Ankle A 1	Adhesive strapping	Good	Nearly 12	Some pain; less endurance	Yes	Yes
I. E., 61, 1920	♀	Ankle A 2x	Gypsum splints	Moderate	6	Pain in wet weather; less endurance	Lower	Less
S. B., 54, 1907	♀	Ankle A 2 with posterior subluxation	Fracture box 13 days; tenotomy, Achilles tendon	Moderate	?	Limp; less endurance	Yes	Yes
T. M., 28, 1921	♂	Ankle A 1	Fracture box 3 days; gypsum splints	Good	6	Painful rigid flat foot; less endurance	Lower	Less

* In this column, ♀ indicates female; ♂, male.

† See footnote to Table 4. A 1 signifies first stage of fracture by external rotation; A 2, second stage of fracture by external rotation, etc.; x, presence also of a posterior marginal fracture of the tibia.

TABLE 5.—*Patients Recovering Only Moderate Function—(Continued)*

Name, Age, and Year Seen	Sex*	Fracture	Treatment	Anatomic Result	Time, Out of Work, Months	Disability	Same Position	Same Wages
E. E., 25, 1920	♂	Ankle B 2a	Screw fixation	Good	6	Pain in wet weather; can walk 2 miles	Yes	Yes
M. H., 46, 1920	♂	Ankle B 2a	Fracture box 3 days; gypsum splints	Good	3	Less endurance	Lower	Less
C. McG., 39, 1919	♀	Ankle B 2b (Fig. 7)	Fracture box 12 days; gypsum splints	Moderate	6	Wore brace one year; less endurance	Yes	Yes
A. V., 28, 1921	♂	Ankle B 3 compound comminuted (Figs. 14 and and 15)	Plate immediately, removed in 10 days (infection); then Steinmann pin	Good	Over 18	Wore brace one year; stiff ankle	No	Less
A. M., 42, 1920	♂	Ankle C 2	Fracture box 3 days; gypsum splints	Good	6	Left foot turns easily; wears arch supporter; very heavy man; right ankle also fractured same time, gives no disability	Yes	Yes
B. P. 59, 1920	♀	Ankle C	Fracture box 6 days; gypsum splints	Good	8	Pain at times; less endurance; has varicose veins	No	Less
R. M., 40, 1914‡	♀	Ankle A 2	Fracture box; circular cast	Bad	Still, after 6 years	Complete	....	...
S. P., 43, 1920‡	♀	Ankle A 2x	Screw fixation (screws removed 10 months later for pain)	Good	12	Pain in wet weather; limited motion; less endurance	Lower	Yes

‡ The functional end-result in the last two cases was bad.

TABLE 6.—*Results in All Cases (Nonoperative)*

Anatomic Result	Total	Functional Result		
		Good	Moderate	Bad
Good	70 (82%)	59 (84%)	11 (16%)	.....
Moderate	14 (16%)	3 (21%)	11 (79%)	.....
Bad	2 (2%)	.....	1 (50%)	1 (50%)
Total	86 (100%)	62 (72%)	23 (27%)	1 (1%)

TABLE 7.—*Results in All Cases (Operative)*

Anatomic Result	Total	Functional Result		
		Good	Moderate	Bad
Good	11 (78%)	8 (73%)	2 (18%)	1 (9%)
Moderate	3 (12%)	2 (66%)	1 (33%)	.....
Bad	.....	.....	.....	.....
Total	14 (100%)	10 (72%)	3 (21%)	1 (7%)

TABLE 8.—*Results in Simple Fractures (All Sites)*

Anatomic Result	Total	Functional Result		
		Good	Moderate	Bad
Good	71 (82%)	60 (85%)	10 (14%)	1 (1%)
Moderate	13 (16%)	4 (30%)	9 (64%)	.....
Bad	1 (2%)	.....	.....	1 (100%)
Total	85 (100%)	64 (75%)	19 (22%)	2 (3%)

TABLE 9.—*Results in Compound Fractures (All Sites)*

Anatomic Result	Total	Functional Result		
		Good	Moderate	Bad
Good	10 (67%)	7 (70%)	3 (30%)	.....
Moderate	4 (26%)	1 (25%)	3 (75%)	.....
Bad	1 (7%)	.....	1 (100%)	.....
Total	15 (100%)	8 (53%)	7 (47%)	.....

TABLE 10.—*Functional End-Results (All Cases)*

	Total		Good		Moderate		Bad	
	A. S. A.*	A. & C.†	A. S. A	A. & C.	A. S. A.	A. & C.	A. S. A.	A. & C.
Simple	625 (68%)	85 (85%)	468 (75%)	64 (75%)	114 (18%)	19 (22%)	45 (7%)	2 (3%)
Compound	289 (22%)	15 (15%)	180 (62%)	8 (53%)	69 (24%)	7 (47%)	40 (14%)	.....
Total	914	100	648 (71%)	72 (72%)	183 (20%)	26 (26%)	83 (9%)	2 (2%)

* A. S. A., American Surgical Association 1921 Report on Fractures of Tibia and Fibula.
† A. & C., present report by Ashhurst and Crossan.

TABLE 11.—*Influence of Age on Functional Result*

Anatomic Result	Total	Functional Result		
		Good	Moderate	Bad
Under 15 Years:				
Good	17 (85%)	17 (100%)	.....	.....
Moderate	3 (15%)	2 (67%)	1 (33%)	.....
Bad	.....	.....	.....	.....
Total	20 (100%)	19 (95%)	1 (5%)	.....
Over 15 Years:				
Good	64 (80%)	50 (78%)	13 (20%)	1 (2%)
Moderate	14 (18%)	3 (21%)	11 (79%)	.....
Bad	2 (2%)	.....	1 (50%)	1 (50%)
Total	80 (100%)	53 (65%)	25 (33%)	2 (2%)

TABLE 12.—*Average Period of Disability (All Cases)*

Fracture	Total				Simple				Compound			
	A.S.A., 1921	Disability, Mos.	A.& C.	Disability, Mos.	A.S.A.	Disability, Mos.	A.& C.	Disability, Mos.	A.S.A.	Disability, Mos.	A.& C.	Disability, Mos.
Shafts	413	5.2	51	4.3	331	4.7	39	3.8	82	7.0	12	5.5
Ankle	233	4.4	35	4.3	225	4.0	35	4.3*	8	5.7	..	...
Total	646	4.9	86	4.3	556	4.4	74	4.0	90	6.8	12	5.5

* One case of simple fracture of ankle resulted in complete disability; not included in above.

TABLE 13.—*Average Period of Disability*

Fracture	All Cases	Average Period of Disability, Months	Simple Fracture	Average Period of Disability, Months	Compound Fracture	Average Period of Disability, Months
Fibula, shaft	5	2.5	4	2.6	1	2.0
Tibia, above middle	2	3.5	2	3.5	..	...
Tibia, below middle	15	3.1	13	3.0	2	3.5
Tibia and fibula, above middle	9	4.7	7	5.0	2	3.5
Tibia and fibula, below middle	20	5.3	13	4.4	7	7.1
Total	51	4.3	39	3.8	12	5.5
Ankle A*	21	4.3	21†	4.3	..	...
Ankle B	9	3.9	9	3.9	..	...
Ankle C	5	5.0	5	5.0	..	...
Total	35	4.3	35*	4.3	..	...

* See footnote to Table 4.
† One with complete disability not included in the above.

SIMPLE FRACTURES

Treatment on Admission.—The usual course of treatment followed in these cases has been about as follows: On admission to the hospital, the skin is carefully washed, and if necessary shaved, and rubbed with alcohol, so as to prevent infection of any bullæ which may develop, or of a more deeply placed hematoma. We are convinced that such infection often arises from neglect in caring for the skin surface. The leg is then placed in a fracture box, gross displacements being corrected, and efforts being made to have the pillow inside the fracture box of such size and thickness as to maintain the limb in as nearly correct position as possible. Pads of raw cotton, folded towels or other material are used between the fracture box and the pillow (not between the latter and the leg) to aid in maintaining reduction. The patient is then sent in his bed (all beds are on wheels) to the roentgen-ray laboratory. In fractures of the shafts of the leg bones, no further reduction is attempted unless gross displacement is shown by the x-rays. In ankle fractures, every effort is made to secure accurate anatomic reposition of the fragments; but in fractures of the shafts, we have been content to secure union without appreciable shortening and without axial or rotatory displacement, even if anatomic reposition was not secured. Thus (Tables 3 and 4), in leg fractures, we secured only 77 per cent. of anatomic repositions (resulting in good function in 91 per cent. of the cases); and in ankle fractures, 86 per cent. of anatomic repositions (with good function in only 74 per cent. of these cases).

Cases Without Gross Displacements.—Usually, the leg has remained in the fracture box several days, or until there occurred subsidence of the swelling present on admission or developing within a few hours. Formerly, circular plaster-of-Paris dressings were applied at this stage, and were left undisturbed until union was believed to have occurred. But since about 1914, such dressings have been abandoned entirely, in favor of molded gypsum splints, as introduced by Stimson. The patient's leg, from toes to midthigh, is bandaged, not too snugly, with flannel bandages, and over these the gypsum splints are applied. These splints are made by soaking, one at a time, the ordinary roller bandage of plaster of Paris (about 10 cm. wide) in warm water, and then running it back and forth on itself as it is unrolled, on a smooth surface (table top), until a splint of suitable thickness and length has been secured. Usually, two or, at the most, three roller bandages are used for each splint, three of which are made, each being applied to the leg before the next is prepared. The first splint passes down the

back of the limb from well above the knee under the calf and heel, and is turned up along the sole of the foot to terminate at the toes. This splint is then bandaged snugly to the leg with circular turns of a flannel bandage, all parts of the splint being carefully covered so that the splint next to be applied will not adhere to the first. The second splint is applied with one end on the dorsum of the foot, passing thence around the outer border of the foot, across the sole and up the inner side of the limb to the midthigh. Its initial extremity should not extend so far across the dorsum of the foot as to touch the edge of the same splint as it passes from the sole up the inner side of the leg, since if these moist margins come into contact one will adhere to the other. The second splint is then carefully covered by a flannel roller; and over it the third splint is applied, covering the dorsum of the foot, the sole, and the outer side of the leg and knee, and is itself held in place by a roller bandage. The great advantage of these splints applied in this way is not only that there need be very little disturbance of the fracture during their application (very much less than in the application of a circular case), but that injurious circular constriction never occurs, and, what is probably most important of all, the two lateral splints can be conveniently removed weekly or oftener for proper dressing of the soft parts without disturbing the posterior splint or the fragments. Patients with these splints have their fractures just as securely fixed as with a circular case, and may be allowed to be out of bed and to use crutches with the same impunity. Crutches seldom are used, nor is the patient allowed to have his leg dependent until three or four weeks after the injury. When union appears good, the patient is encouraged to bear a little weight on the limb, and then one of the gypsum splints is discarded at a time, until usually about the sixth to the eighth week the patient is using crutches without any splints. Seldom has troublesome swelling occurred during convalescence. This is attributed to the care of the soft parts during the time the bones were uniting. Weekly or oftener, when the lateral splints are removed, the patient is able to make active movements of the foot without disturbing the fracture; and as soon as enough union is present to prevent displacement of the ends (usually after two weeks), the entire limb can be raised by the surgeon from the posterior splint, and a little motion may be permitted at the knee. Very light *effleurage* is employed by the surgeon at each dressing. This amounts to little more than sponging the skin with alcohol, drying it well, and rubbing in some talc powder with the hand. It is seldom found necessary to have formal treatment by baking and massage instituted during convalescence when proper care has been taken of the soft parts from the first.

In shaft fractures with marked displacement and in ankle fractures in every case with any displacement whatever, efforts are made as soon as possible to correct the displacement. For this, a general anesthetic is given almost always. In shaft fractures, attempts have been made to secure reduction by dressing the leg in Pott's position (lying on its outer side with the knee flexed), but without success. Subsequent roentgen-ray examination has seldom shown any marked improvement in the position of the bones, even when the appearance of the soft

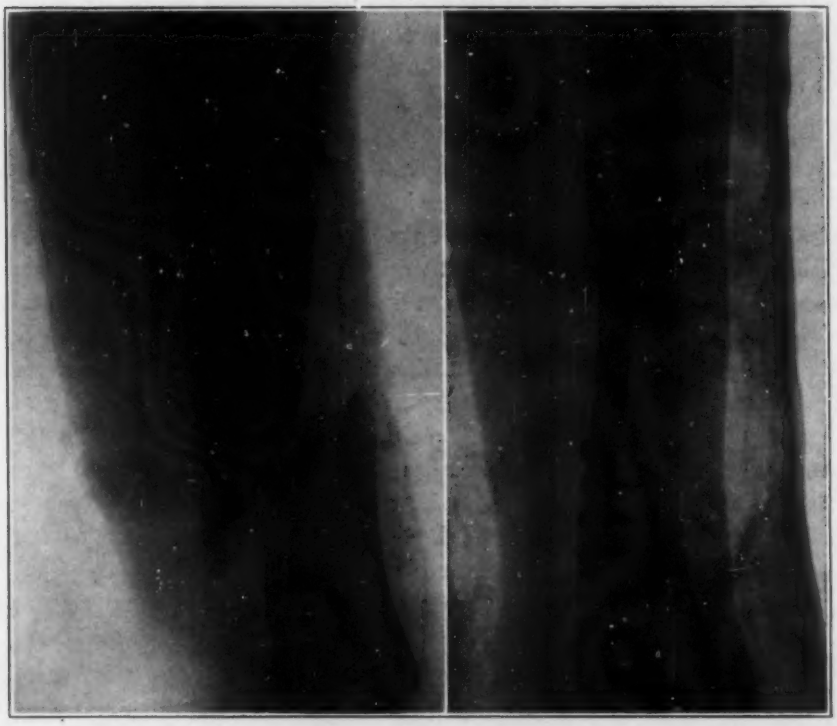

Fig. 1 (E. G., man aged 32, Sept. 16, 1916, on admission).—Left: Compound fracture of tibia and fibula from kick by horse. Free bleeding was controlled by compress. Attempted reduction on fracture table, with mechanical traction under anesthesia was not successful. A plate was applied seven days after injury. Right: Appearance ten days after operation. The patient was out of work six months. A perfect anatomic and functional result was obtained.

parts indicated good reduction; and in a few cases, the displacement has been increased when Pott's position was employed. In some cases with marked displacement (Fig. 1), it is evident that attempts at closed reduction will do more damage to the soft parts than will an operation; and in such cases, no attempts at reduction are made until the bones are

exposed at operation. In other cases, particularly comminuted fractures, it is evident that, even if secured, reduction could not be maintained without continuous extension; and in these, the principle of skeletal traction has been employed by means of the Steinmann pin through the calcaneum. This plan will be described in speaking of compound fractures. In three cases of fractures in the upper third

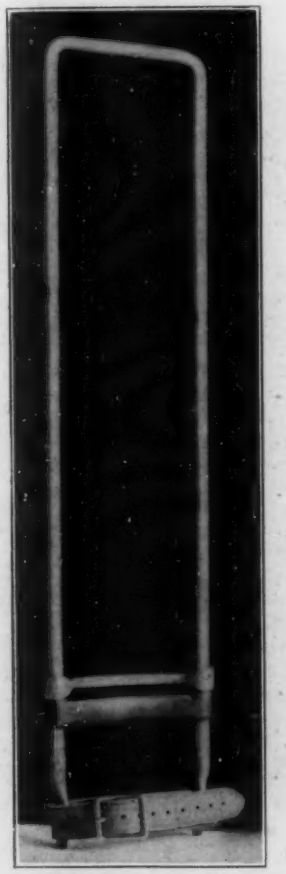

Fig. 2.—Equinus-lever of Gwilym G. Davis. The leather strap passes across the instep, and the cross bars beneath the ball of the foot. The operator, steadying the far end of the lever in his own axilla, has complete control of the patient's foot.

of the tibia, the ordinary Buck's extension apparatus was advantageously employed. In ankle fractures, reduction frequently may be secured by manual manipulation under anesthesia. In a few cases, we have employed with advantage the equinus lever of G. G. Davis

(Figs. 2, 3, 4); in others, it has failed to procure reduction (Figs. 5 and 6). In two cases (seen in 1907 and in 1912), in which the fracture was not reduced for two weeks and for three weeks, respectively, it was necessary to perform a tenotomy of the Achilles tendon. These patients did not secure perfect function. Each was 54 years of age, and recovered with somewhat lessened endurance and a slight limp. If reduction of an ankle fracture cannot be secured after one or two

Fig. 3 (L. K., woman, aged 69, Sept. 5, 1916, on admission).—Left: Ankle fracture by external rotation, second degree: (1) spiral fracture of fibula through inferior tibiofibular joint, (2) fracture of internal malleolus; complicated by a posterior marginal fracture of the tibia, and with posterior subluxation of the foot (A2x); anteroposterior view before reduction. Right: Lateral view.

attempts under general anesthesia, operative reduction is advised. It was adopted in six of seventy-nine cases of simple fracture, and in all of them screw fixation was employed (Figs. 5 and 6). Some patients refuse any operation (Fig. 7).

Delbet's Gypsum Apparatus.[2]—During the last year, we have employed this apparatus in every case of leg fracture in which it did not seem contraindicated; that is, in about ten cases. We have to thank Dr. Mercier, Dr. Bourgeois and their staff, at Notre Dame Hospital, Montreal, for demonstrating the application of this apparatus. The chief advantages of the apparatus are: 1. It is applied during continuous traction on the foot by weight and pulley, this traction serving to secure sufficiently accurate reduction of fractures of the

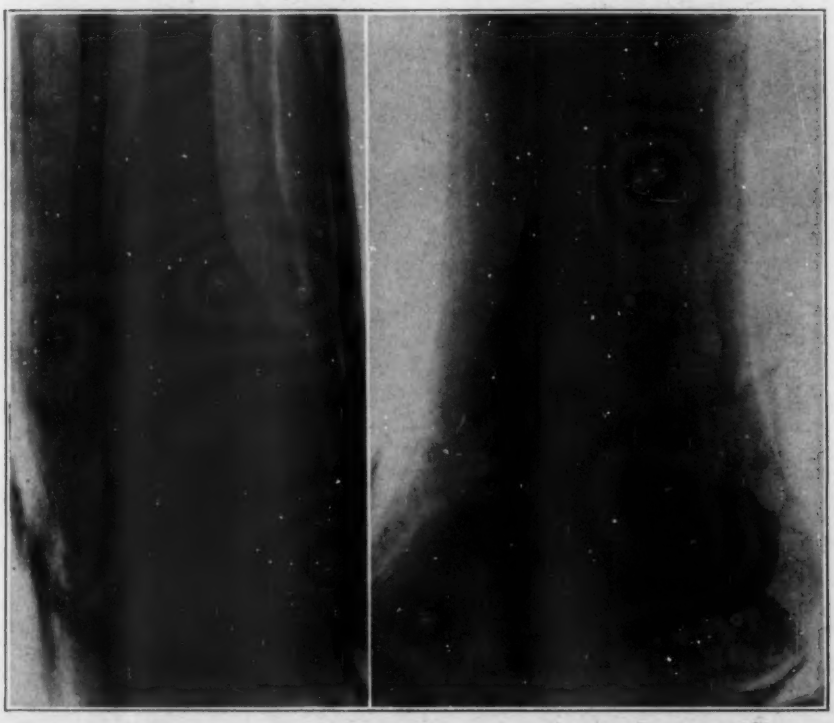

Fig. 4.—Same case as in Figure 3. Left: Appearance after reduction by means of the equinus lever. Gypsum splints (Stimson) were used (antero-posterior view). Right: Lateral view after reduction. The patient was in hospital about eight weeks, and resumed her housework on her return home. A perfect anatomic and functional result was obtained.

shafts without any anesthetic. 2. When applied and as soon as the plaster of Paris has set, the weight extension may be removed, since the apparatus fits snugly to the condyles of the tibia above and to the malleoli below, preventing any subsequent shortening. 3. It leaves both the knee and ankle joints free, so that the patient can move them from

2. Delbet, Pierre: Méthode de traitement des fractures, Paris, 1916.

Fig. 5 (C. K., man, aged 52, Jan. 13, 1917).—Left: Ankle fracture (A2x) after two attempts at reduction, the second attempt aided by the equinus lever; anteroposterior view. Right: Lateral view. Reduction was not obtained.

Fig. 6.—Same case as in Figure 5, showing result of arthrotomy and screw fixation, eleven days after injury. The patient was out of work thirteen weeks. A perfect anatomic and functional result was obtained. The screws were still in place, over seven years after operation.

the start, and thus, by constant use of his leg muscles, materially shorten the period required for consolidation of the bones, and prevent the occurrence of the atrophy of disuse. 4. The patient can leave his bed and begin to walk with crutches during the first week or ten days. 5. Delbet found in his own cases that the average time the splint was worn was thirty-five days, the fragments being then firmly united and all external support discontinued.

The materials required for the application of the apparatus are:

1. A hard flat table with no padding to support the fractured leg. Such support prevents the posterior sagging of the fragments always

Fig. 7 (C. McG., woman, aged 39, July 17, 1919, on admission).—Left: Ankle fracture (B2b), typical Pott's fracture, with (1) fracture of internal malleolus, (2) diastasis of tibia and fibula and (3) fracture of fibula well above the inferior tibiofibular joint (anteroposterior view). Right: Lateral view, showing posterior subluxation of foot (note absence of a posterior marginal fracture of tibia). Patient first came under the authors' care two weeks after injury. Three attempts at reduction under an anesthetic failed to secure anatomic reposition. The patient refused operation. She was out of work six months, but held her former position at the same wages. A moderate anatomic and functional result was obtained. Pain after much motion, and less endurance were her complaints three years later.

seen in shaft fractures when the limb is placed on an upholstered surface, such as even the firmest mattress. In our own work, we have used a thin board which is laid on top of the mattress (Fig. 8); and we

have had a pulley attached to the board at such a height that traction over it will be directly in the axis of the leg bones, and with the pulley movable laterally on its axis, so that any lateral deformity at the site of fracture can be corrected by shifting the pulley to right or left without in any way disturbing the limb.

2. A scultetus (many-tailed) bandage, made by stitching together at their centers enough rather narrow strips of bandage (each about 50 cm. long) to extend from the heel to the knee. Its ends may be wrapped in cardboard for convenience in handling.

3. Weights for traction. From 16 to 22 pounds (7 to 10 kg.) is required.

4. Material such as tarlatan or crinoline for making the apparatus. This should be cut into pieces of the following dimensions: the two side splints are each of twenty-four thicknesses, 65 by 8 cm. The

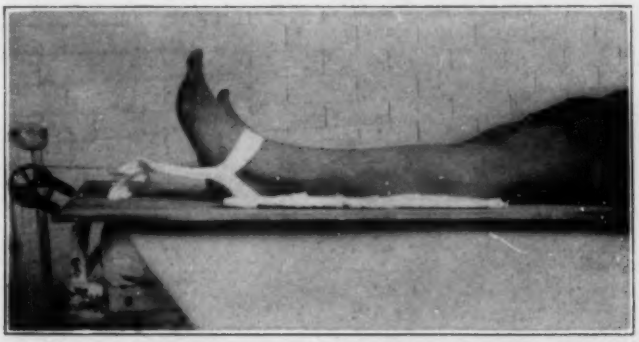

Fig. 8.—Method of application of Delbet's apparatus for fractures of the leg. The board is laid on the bed, with pulley for weight extension. There are traction loops over the instep and heel, and a scultetus bandage beneath the leg.

band which encircles the leg below the knee is of sixteen thicknesses, and measures 65 by 5 cm. The band which encircles the malleoli and heel is also of sixteen thicknesses, 65 cm. long, and cut so that its middle portion is 12 by 19 cm., while its right and left thirds are only 5 by 23 cm. long. In the middle third, a semicircular notch is made in the projecting portion to receive the point of the heel. These four splints should be basted together down their middle, for convenience in handling (Fig. 9).

Application of the Delbet Apparatus.—The board with pulley attached is placed under the fractured leg with as little disturbance as possible, and an assistant holds the patient's toes to prevent rotation of the leg. The leg should be cleansed, and if necessary shaved. It should

always be well powdered (talc powder is excellent for this purpose [3]). The scultetus bandage is then carefully drawn under the leg, without disturbing the latter more than is absolutely necessary. Next, a stirrup for traction is made by passing one strip of flannel bandage (about 3 by 45 cm.) beneath the Achilles tendon, and another of the same dimensions across the dorsum of the foot just below the ankle joint. These strips are arranged so that their centers lie in the midline of the heel and ankle, and their ends are overlapped just below and posterior to the malleoli. While the surgeon holds the ends properly

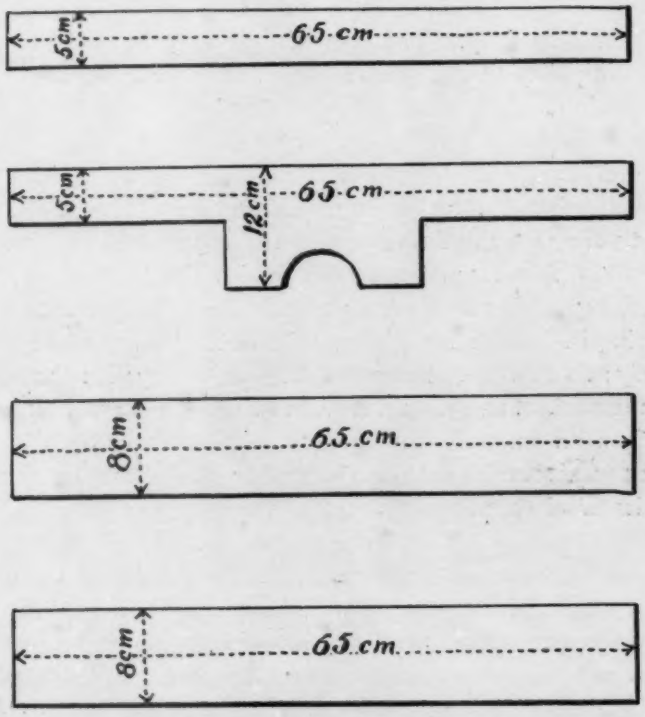

Fig. 9.—Diagram showing the dimensions of the crinoline bands of which Delbet's apparatus is composed. The two lateral bands are made of twenty-four thicknesses of crinoline, and the circular bands of sixteen thicknesses each.

overlapped, the nurse sews them together. This may be facilitated by turning the overlapped ends temporarily upward above the malleoli. Next the free ends of these traction strips are sewed or tied to each

3. As the plaster-of-Paris splints are to be applied directly to the bare skin, discomfort may arise from the hairs sticking to the plaster while moist. Shaving will prevent this, but we have found generous powdering sufficient. It is more satisfactory than greasing, as the latter has a tendency to prevent the plaster of Paris from setting.

other a convenient distance below the sole of the foot; and to the loop thus formed is fastened the rope passing over the pulley and supporting the weights. The weights should be added gradually. Repeated measurements of the fractured leg (from the lower border of the patella to the tip of the internal malleolus) will show its shortening being gradually overcome as the weights are cautiously increased up to a maximum of about 10 kg. Frequently, less weight is enough. As soon as the weights begin to act, the patient's pain ceases.

No effort should be made to push or mold the bone ends into position. Any such attempt will produce pain and muscular spasm, and will totally defeat the object to be gained, which is the gradual reduction of the deformity. The line of pull may be altered readily by shifting the pulley to one side or the other without causing the patient any discomfort. As soon as reduction has been secured, as ascertained by measurement and the restoration of the normal axis of the limb, a plaster cream should be made. About six cupfuls of cold water is placed in a rather shallow but large basin, and plaster of Paris is slowly sifted into the water until the powder no longer sinks rapidly. By this time, a little plaster will have collected on the bottom of the basin; and then, but not until then, should the hand be put into the cream for stirring it. This stirring should be done slowly and regularly and uniformly; no churning is permissible. Delbet says it is better to have a cream too thin than too thick. When it is of the consistency of very thin cream, all four of the crinoline splints should be placed in the mixture at the same time, to prevent unequal distribution among them of the plaster of Paris. When they have become well impregnated, they are taken out and spread out flat and in order.

The band which goes around the malleoli is drawn under the bridge formed by the Achilles tendon without moving the leg, and is pulled down by see-saw motions until it is arrested by the heel. For the time being, its ends are spread out flat on the fracture board. The band for below the knee is next pulled beneath the popliteal space, and drawn downward by see-saw motions until arrested by the calf; and its ends are spread out flat on the fracture board. Next, the two lateral bands are applied beginning just below the level of the knee joint (this is at the lower border of the patella), and extending to within 1 cm. of the sole of the foot at the heel. The bands are then doubled back on themselves, so that the lower one third of the leg is supported by a double thickness. When these lateral bands have been gently molded to the sides of the leg and the malleoli, the circular band already in place beneath the heel is drawn snugly around the malleolar region on top of the two lateral bands, but without any constriction. The long ends of this circular malleolar band are to be crossed on themselves

across the front of the leg at a point above where the tendon of the tibialis anticus becomes subcutaneous. This point may be observed on the normal leg, and the splint arranged to correspond. Neglect of this will lead to the development of a pressure sore at this point. Finally, the upper circular band, surrounding the condyles of the tibia, is drawn snugly but without constriction, around the leg below the knee, and its ends are crossed in front at a point above the crest of the tibia, which is also liable to pressure sores. The usual mistake is to put this upper circular band too high, so that it interferes with flexion of the knee (Fig. 10).

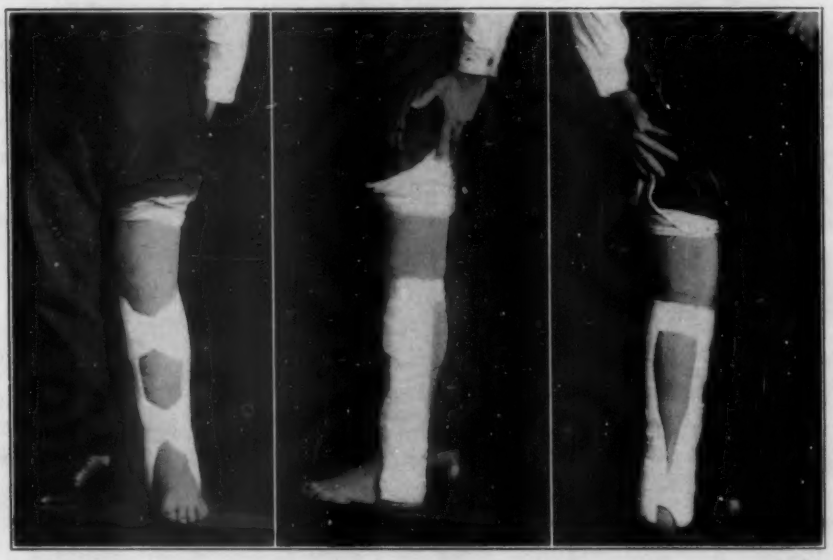

Fig. 10.—Delbet's apparatus for fracture of the leg. The weight is borne on the foot itself, not on the ends of the splint. The lower band crosses above the prominence made by contraction of the tendon of the tibialis anticus. The upper band should not come so far below the tubercle of the tibia as to press on the crest of the tibia. The space for projection of heel should be noted.

Last of all, the scultetus bandage is fastened up, beginning at the heel; and the whole apparatus is carefully molded to the malleoli and tibial condyles as it sets. So soon as it has become reasonably firm, the weights are removed, and the stirrup applied for extension is cut and withdrawn. Neglect to remove it may cause a slough over the dorsum of the foot or over the heel. Usually, the weights do not have to remain in place for more than fifteen or twenty-five minutes from beginning to end of the procedure. The scultetus bandage is removed in twenty-four or thirty-six hours, leaving the gypsum apparatus in place. To

insure proper "setting," the plaster of Paris must be fresh and of good quality; and it is a wise precaution to wash the starch out of the crinoline bands before immersing them in the plaster cream, and to sprinkle some of the dry plaster over the various bands just before they are applied to the leg.

For the first day or two after the Delbet apparatus has been applied, it is well to keep the limb well elevated on pillows, and surrounded with icebags. This tends to prevent injurious swelling and formation of blebs. In a few cases, it may be necessary to remove the apparatus on account of the swelling. Blebs appear not beneath the gypsum apparatus but on the exposed skin. They should be punctured with a sterile knife and dusted with sterile powder, and then usually may be disregarded, giving no further trouble. If the apparatus is not applied until swelling has developed, it usually is necessary to apply a second one within a few days when subsidence of the swelling causes it to become loose. Of 123 cases under Delbet's care, a second apparatus had to be applied in sixty-eight; twenty-eight patients had three plasters, and three patients had four plasters. Only in twenty cases was a single application of the apparatus sufficient.

The subsequent care and treatment of patients wearing the Delbet splint form an integral part of the treatment and must never be neglected. Within the first week or ten days, the patients are gotten up on crutches and taught to walk. Putting the foot flat on the floor, they must be made to dorsiflex the ankle and bend the knee at each step, thus bringing into function both joints, and preventing the atrophy of disuse or joint stiffness. This active mobilization has a singular tendency to promote rapidity of union in the fracture. Delbet says that, in his cases of simple fracture, the average stay in hospital was twenty-four days; whereas, the statistics of the Public Health Service of Paris show that, for simple fractures of the legs under the usual treatment, the average stay in the hospital is from two and one-half to three months. In these latter cases, there is first a period of from thirty-five to forty-five days in the circular plaster-of-Paris case, and then a further period of two or three months or longer for massage, etc. This makes the total period of disability between four and five months, for simple fractures of the leg. This corresponds to the period of disability in the statistics of the Fracture Committee of the American Surgical Association. While Delbet says he does not accurately know the end-results in patients treated by his method, he is convinced the patients are absolutely cured when the apparatus is removed about the end of the fifth week (thirty-five days). Of sixty-five cases traced, he considered "good" results were obtained in sixty, though ten of these

patients limped, and three had shortening of 3 cm. Evidently, he is not so strict in his definition of good results as the Fracture Committee of the American Surgical Association. Delbet uses this apparatus also in ankle fractures, considering it especially adapted to them. Of fifty-five end-results of ankle fractures, he considered fifty-three good. He thinks his apparatus least satisfactory for fractures in the upper third of the tibia and fibula, where fixation of the fragments is nearly impossible unless the knee joint also is immobilized.

The patients in whose cases we have used the Delbet apparatus have been treated too recently to be included in the present report. However, we have found that posterior sagging of the fragments, not infrequent with the former methods of treatment, can almost always be overcome; that the shortening almost always is inappreciable or absent; that the patients get about on their feet sooner, and that union occurs more rapidly. The Delbet splint was also found very useful in a case of delayed union. Applied at the end of the third month, it brought about firm union in three weeks' time. In recent cases, it should be applied at once, before the leg and ankle have swelled. Early reduction may prevent too great swelling. If this swelling occurs in spite of the prompt application of the apparatus, there will be less tendency for shortening and deformity to develop when the apparatus is removed several days after the injury than there was when it was applied; and if the shortening and deformity are allowed to remain uncorrected at the time of the accident, they become daily more and more difficult to overcome.

COMPOUND FRACTURES

There were fifteen cases of compound fracture among the 100 patients traced; fourteen of the shafts, and only one involving the ankle joint. They have readily divided themselves into two classes: (1) those with small skin wounds (2 or 3 cm. or less in length), usually produced by the bones breaking through the skin, and (2) those with large lacerations of the skin and muscles, usually produced by direct violence.

1. The former class, with small skin wounds, have been treated as simple fractures; that is to say, the leg has been cleansed (with iodin), and the wound or wounds have been covered by alcohol compresses, and allowed to heal without primary operation. If operation seemed required for reduction, as it did in four of thirteen cases of this nature, it was not undertaken until the period at which it would have been performed if the fractures had been simple and not compound. By this time (a week or ten days after the injury), the wounds in the soft parts had healed, and the fracture had been converted into the simple type

(Fig. 1). If operation did not seem indicated, the steinmann nail extension was preferred to the Delbet splint when gross displacements of the fragments existed, and especially in comminuted fractures (Figs. 11, 12, 13).

The Steinmann nail may be inserted with local anesthesia only, but a general anesthetic (gas) is preferable. The heel, being properly sterilized, is held firmly in the surgeon's left hand, and a longitudinal

Fig. 11 (A. H., woman, aged 47, Dec. 18, 1915, on admission).—Right: Compound comminuted fracture of tibia and fibula from a fall on icy street. The bones, which protruded through the skin on both sides of the leg, were swabbed with iodin and reduced (anteroposterior view). Left: Lateral view. Steinmann nail traction was employed for eighteen days (compare Figures 12 and 13).

incision about 1 cm. long is made directly down to the calcaneum, about half way between the external malleolus and the sole, just posterior to the line of the fibula. The edges of this incision are held apart by an assistant, with Allis forceps, and the nail, fixed in its handle,

is bored through the calcaneum, care being taken that it passes transversely and not obliquely to the long axis of the leg. It passes through the bone readily as the surgeon keeps constantly pushing it ahead with a rotatory motion in supination only. To pronate the hand while boring the nail through the bone will unscrew the two halves of the nail at their junction. When the point is felt beneath the skin on the opposite

Fig. 12.—Same case as in Figure 11. Left: Anteroposterior view, five days after traction of 7.5 kg. (16 pounds) by Steinmann nail. Right: Lateral view. Shortening is almost overcome, but there is still lateral displacement of more than half a diameter.

side of the heel, a small longitudinal incision is made over it; the skin edges are held apart by Allis forceps, and the point is brought as far out beyond the skin as the other end projects on the opposite side of the heel. The handle is then detached, and a snugly fitting piece of

rubber tubing is passed over each end of the nail so as to prevent the latter from coming into contact with the skin or subcutaneous fat at any point.

Lambotte has pointed out that neglect of this precaution has often resulted in necrosis of the skin edges where these touch the nail; whereas, when they are protected by rubber tubing, they remain healthy. Finally, the tongs are applied, being wrapped at their junction with the

Fig. 13.—Anteroposterior and lateral views of case shown in Figures 11 and 12, two weeks after traction of 7.5 kg. (16 pounds) by Steinmann nail. Shortening is overcome, reduction fair and lateral displacement less than one-quarter a diameter. The anatomic and functional result is moderate (after seven years, the patient still has pain in wet weather).

nails in abundant sterile gauze; and the weights are attached. From 15 to 22 pounds (8 to 10 kg.) is sufficient. Usually, we have employed a posterior gypsum splint (Stimson) along with the nail extension. After ten days or two weeks, the amount of weight is gradually

diminished, the position of the bones being controlled by the roentgen ray; and about the end of the third week or during the fourth week, the traction apparatus is removed. This is readily done without an anesthetic, the projecting sharp point of the nail being caught in a sequestrum forceps, and held firmly while the blunt end is unscrewed with the handle which fits it, the two halves thus being extracted through their proper sides of the calcaneum without carrying any possible contamination across it.

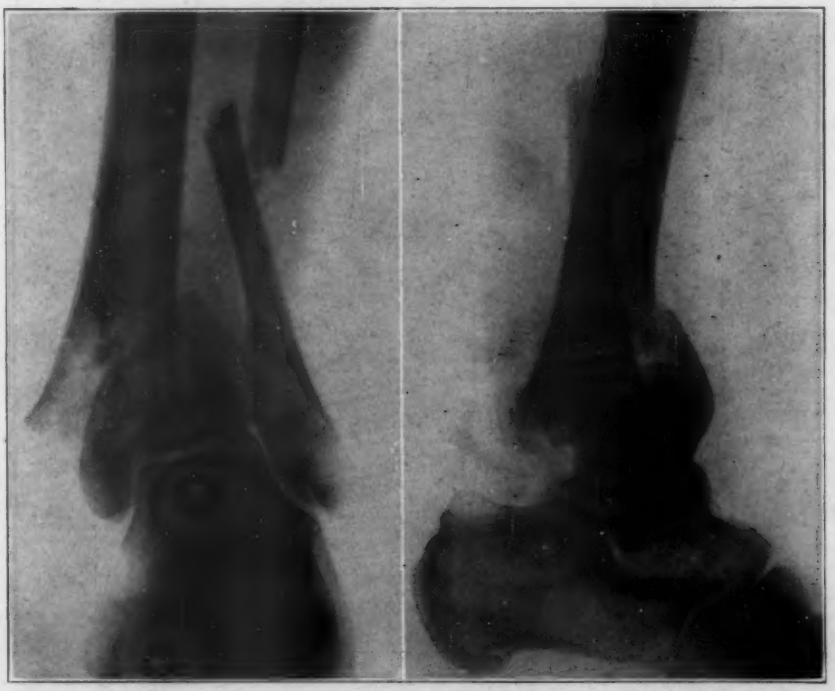

Fig. 14 (A. V., man, aged 28, Sept. 17, 1921, on admission).—Compound fracture of left tibia and fibula involving the ankle joint (B3): (1) fracture of entire lower end of tibia (representative of the internal malleolus in the typical Pott's fracture), followed by (2) fracture of the fibula well above the inferior tibiofibular joint, resulting from a fall from a height, the patient landing on the foot. Immediate operation was performed.

Of the ten cases in which skeletal traction by the Steinmann nail was employed, it proved efficient in eight, though in one of these cases the nail broke at its center screw-joint while the weights were attached. This accident occurred at the end of the third week, when it was time for its removal. Aside from causing the patient discomfort for a few hours, until its removal, no other inconvenience was experienced. In

another case, a defective nail broke in half at the screw joint as it was being inserted. The sharp end had just emerged from the bone on the distal side of the limb but could not be extracted. The blunt end was removed in its handle. The sharp end was temporarily disregarded; but when the patient was returned to the operating room a week later, for fixation of the tibia by plate, it was found, as had been anticipated,

Fig. 15.—Same case as in Figure 14 one week after operation. Ten days after operation the plate was removed because of infection, and a Steinmann nail was applied (Fig. 16).

that enough rarefaction had already occurred around the remaining portion of the nail to allow its being extracted easily, though only the tip of its sharp point was available for the hold of forceps (Fig. 1). In one case, traction (instituted on the sixth day) with a weight of 22 pounds (10 kg.) on the nail failed to improve the position of the fragments, which were subsequently plated.

Cultures were made in almost all cases from the sinuses through which the traction nails passed, at the time of removal of the latter. With one or two exceptions, which gave a growth of staphylococcus, all cultures remained sterile; and all, even those with positive cultures, healed rapidly when the nail was removed. Though the tunnel in the calcaneum may remain visible by roentgen rays for many months, no discomfort has been experienced by the patients. One patient, however, fourteen months after the injury still complained of hyperesthesia in

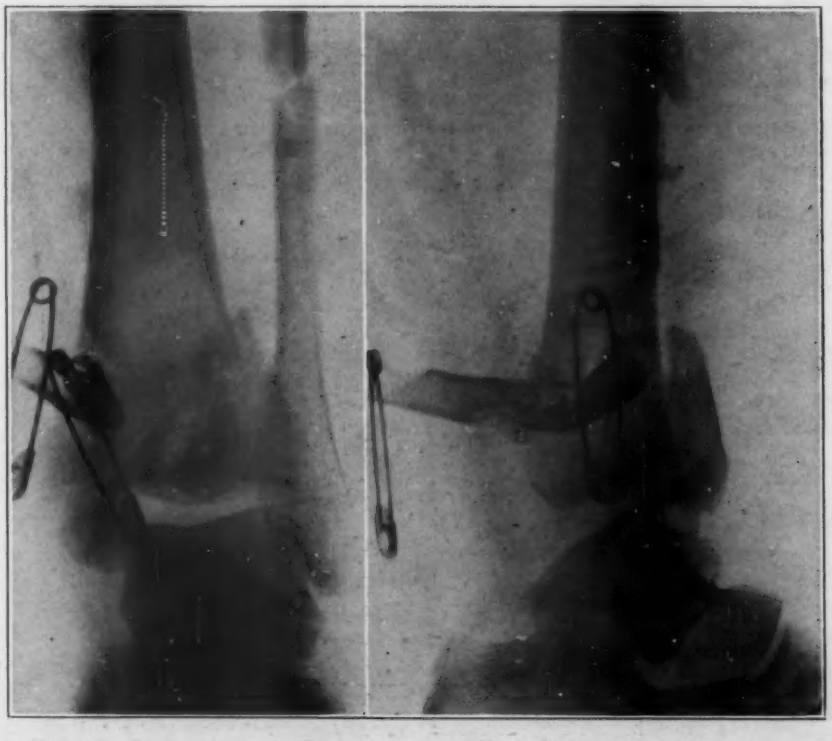

Fig. 16.—Same case as in Figures 14 and 15. A Steinmann nail was inserted, Sept. 27, 1921, ten days after injury, when the plate was removed. The drainage tube emerging through counter-incision at dependent point may be seen. The Steinmann nail was removed, November 1 (five weeks later).

the skin overlying the nail punctures, probably from inclusion of a skin nerve in the scar.

2. The second class of compound fractures, with large wounds of the soft parts, comprised only two cases. They were treated by immediate antiseptic operation, débridement, excision of devitalized tissues, fixation of the bone fragments, drainage and partial closure of the wounds. In neither case could complete closure have been secured

without some form of plastic operation to fill the areas of skin destroyed by the accidents; and it was believed to be a better course to allow the wounds to heal by granulation. Dependent drainage should always be secured, a counter opening being made for this purpose posterior to the fibula, and a drainage tube being passed across the leg at one or more points. In the first case, involving the ankle joint (Fig. 14), the tibia was fixed by a plate and fairly accurate reduction secured (Fig. 15), but owing to a rise in temperature, after ten days the

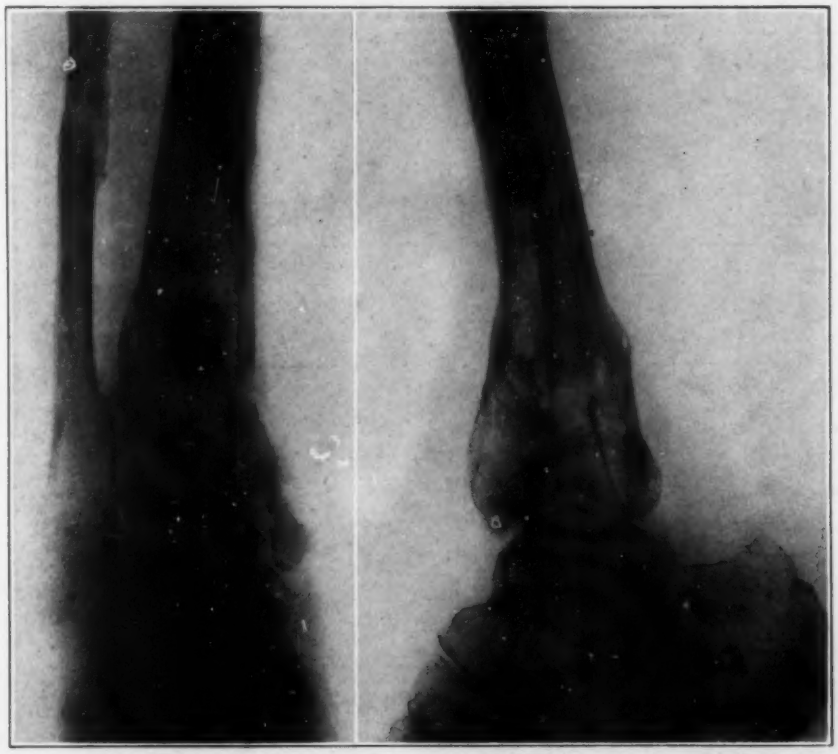

Fig. 17.—Same case as in Figures 14, 15 and 16, one year after injury. The tunnel for nail is still visible in the calcaneum in the lateral view. The patient wore a brace, for a year. He was out of work eighteen months. A good anatomic result with moderate function was obtained. The only disability is a stiff ankle, but the patient cannot resume the same position (which involves climbing telegraph poles) and makes less wages.

gypsum splints were removed, under general anesthesia; and it was then found that the plate had been pulled loose from the lower fragment of the tibia (probably during removal of the splints). The plate was therefore removed entirely, and skeletal traction by the Steinmann nail applied (Fig. 16). This resulted in final union without

deformity, though several sequestrums were removed at another occasion, and a sinus (barely moist) persists eighteen months after the accident. This patient wore a leg brace for a year after the accident; was out of work eighteen months, and has no motion in his ankle joint. He is counted as having recovered with good anatomic and moderate functional results (Fig. 17). He refused secondary ampu-

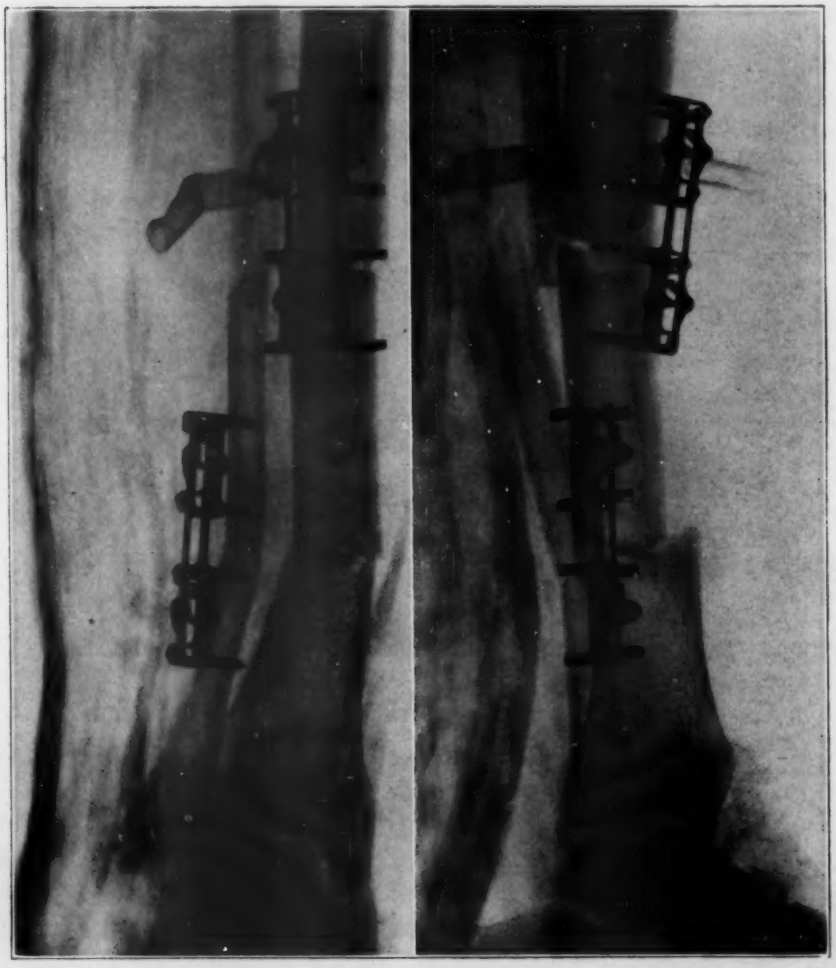

Fig. 18 (J. M., man, aged 32, Aug. 9, 1922, after operation performed immediately on admission).—Double compound fracture of tibia and fibula, showing temporary clamps used to fix the compound fractures; also a Steinmann nail in calcaneum, and drainage tube emerging through dependent counter-incision. The clamps and traction nail were removed three weeks later. The patient was in hospital ten weeks, and was discharged with firm union, wearing a brace. He was out of work nine months. Anatomic and functional result was moderate (has less endurance than before injury, but no other disability).

tation of the leg, which undoubtedly would have greatly shortened his convalescence. In the only other case in this series, of compound fracture with much destruction of the soft parts, there was a double fracture of both tibia and fibula. The compound fracture of each bone was fixed by a removable clamp (Fig. 18), and the simple fracture of each bone was disregarded, except for continuous traction by a Steinmann nail. The traction nail and the clamps were removed three weeks after the injury, and the soft parts continued to heal uninterruptedly, though the wound was not completely closed for nearly eight months after the accident. The patient was out of work nine months, and secured a moderately useful leg without shortening, but neither the functional nor the anatomic result was perfect.

TABLE 14.—*Operations for Fractures of Tibia and Fibula*

Site	Simple Fractures		Compound Fractures	
	Total Number	Operations	Total Number	Operations
Leg	58	5	14	4
Ankle	79	6	1	1
Total	137	11	15	5

TABLE 15.—*Operations Employed*

Operations	Simple	Compound	Total
Plate	4	5	9
Screws (all ankle fractures)	6	0	6
Open reduction	1	0	1
Total	11	5	16

OPERATIVE TREATMENT

In the entire series of 152 cases (seventy-two fractures of the shafts of the leg bones, and eighty involving the ankle), operation was employed in sixteen patients, fourteen of whom have been traced. These sixteen operations do not include the use of the Steinmann nail for traction in ten cases, tenotomy of the Achilles tendon in two cases, nor one case of arthrotomy of the knee joint (with immediate closure) for hemarthrosis.

Except in compound fractures with great destruction of the soft parts, no immediate operations have been done, a delay of from five to ten days always having been allowed for proper sterilization of the skin. In a series of 130 operations in civil life by one of us (A) for simple fractures of various bones in the body, only one infection has occurred, and this was clearly due to too early operation before the

bullae which followed the original injury had entirely healed.[4] Among the nine cases in which a plate was inserted in the leg, only once has the plate had to be removed subsequently, and then only because the patient was kicked in the shin by a horse, one year after the operation, the horse's kick causing a lacerated wound which exposed the plate.[5] In the tibia, the plate has always been placed on its fibular surface, never subcutaneously, so as to avoid so far as possible any tendency toward such an accident. Of the six cases in which screw fixation[6] was employed for recent fractures of the ankle, the screws were removed in one case about a year after operation, because of persistent pain in the ankle, which was somewhat lessened by their extraction. This case is considered as having a bad functional result. The only case in which open reduction was adopted without direct fixation of the bone occurred in a child, the fracture resembling that shown in Figure 1. In this case, several ineffectual attempts to reduce the fragments had been made by another surgeon (under anesthesia), before the child came under our care and the soft parts were in very bad condition, though the fracture was not compound. In such fractures as these two, it seems to us doubtful whether any attempt at closed reduction is judicious, as we believe it will cause more injury to the soft parts (even were the efforts successful) than operation would entail.

In 78 per cent. of operative reductions, anatomic reposition was secured; in three cases only moderately accurate reduction was secured. In no case, we believe, could as good function have been obtained without as with operation.

CONCLUSIONS

Early reduction of all gross displacement is urged; and in ankle fractures, anatomic reposition should be the goal in view. Stimson splints of plaster of Paris are far superior to circular cases, because permitting proper care of the soft parts at suitable intervals, and preventing atrophy during the process of union, as well as stiffness and swelling during convalescence. The Delbet apparatus has certain additional advantages, notably that of allowing active motion of the knee and ankle joints while the fracture is uniting, as well as hastening the process of union, and shortening the period of disability. In compound and in simple comminuted fractures, traction by the Steinmann nail

4. In one or two other cases, there was superficial infection of the skin at one or more points, but not extending beneath the superficial fascia.

5. There has recently been brought to the notice of the senior author a patient still carrying in the tibia a plate inserted for nonunion by his father (Dr. John Ashhurst, Jr.), twenty-seven years ago.

6. Ashhurst, A. P. C.: Screw-Fixation in Joint Fractures, Med. & Surg. (Oct.) 1917.

has given admirable results. If direct bone fixation is adopted in compound fractures which require immediate open reduction, the fixation apparatus should be removable as soon as fair union is secured. The period of disability for fractures of the shafts of the leg bones in this series averaged (in simple fractures) three and eight-tenths months, nearly a month less than the average period of disability shown by the statistics of the American Surgical Association; and in compound fractures, it averaged five and a half months or about six weeks less than for corresponding cases tabulated by the American Surgical Association. The period of disability for ankle fractures averaged approximately the same in both series (Table 10).

TREATMENT OF FRACTURES BY ORTHOPEDIC METHODS *

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NEW YORK

ORTHOPEDIC ASPECT

Surgery of the extremities has made tremendous progress in the last decade, easily keeping pace with surgery of the abdomen and of the brain. Many new methods of treatment and operation have been devised, and the demand for better results was never so acute as at present. Fractures constitute an important part of the surgery of extremities and the results are more open to criticism than are other operative results. The demands of the public and the general practitioner are different from those of twenty-five or even ten years ago. Some of you may still be using methods in vogue at the time of your graduation, and with good results; but a brief résumé of some modern methods may be of interest. Even if one does not treat fractures, a definite idea of modern treatments and prognosis is of value, enabling one to give the proper information to the patient and his relatives.

The question remains as to whether fractures should be treated by general surgeons or by orthopedic surgeons who claim that their methods have revolutionized bone surgery. Moorehead says, in this connection, that "unless surgeons will pay the same attention to fractures as to abdominal surgery, orthopedic surgeons will grab all the fractures." Osgood [1] justly concludes: "As we watch the trend of surgery, we find in the large centers a seemingly increasing tendency for the general abdominal surgeon to refer acute as well as chronic lesions of

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* From the surgical service of Fordham Hospital.

* Read before the Bronx County Medical Society, Dec. 20, 1922.

* The orthopedic aspect is presented by Dr. Boorstein; the roentgenologic aspect by Dr. Landsman.

1. Osgood, R. B.: The Standardization of Methods of Treatment in Orthopedic Surgery and in Industrial Surgery of the Extremities and Spinal Column, Illinois M. J. **39**:342 (April) 1921.

the extremities and spinal column to surgeons whose interest has led them to devote special attention to these lesions."

The progressive surgeon does not hesitate to seek the aid of an orthopedic surgeon when the future good of the patient demands it; nor does he hesitate to accept a new method of treating fracture just because it has been invented by an orthopedic surgeon. The use of Whitman's abduction method of treating fracture of the neck of the femur, Albee's bone graft and Thomas' splint are examples of his open-mindedness. The same holds true of the progressive orthopedic surgeon.

In many general hospitals, of which the Massachusetts General Hospital and the New York Hospital are examples, separate fracture services have been instituted. In others, the general surgeon acts in consultation with the orthopedic surgeon. This is particularly true of the difficult cases.

Ollerenshaw,[2] in an extensive article, makes a strong plea for the establishment of special fracture services in general hospitals in charge of surgeons especially interested in bone and joint lesions. The importance of the inclusion of the outpatient cases in such a service is emphasized. He considers about 6 per cent. of the total number of hospital beds are necessary for such a service, and he is convinced that such a plan will avoid many of the bad results which now arise from the general treatment of fractures.

Scudder,[3] who organized one of the first fracture services in America, at the Massachusetts General Hospital, has been impressed by the necessity for improving results in the treatment of fractures throughout the country. He makes the following suggestions: (*a*) special wards restricted to the treatment of fractures; (*b*) a special fracture personnel of surgeons under a chief of service of broad experience; (*c*) a special fracture outpatient clinic under the charge of the special fracture service; (*d*) improvement in the methods of teaching how fractures should be treated and more time for the subject in the medical school curriculum; (*e*) graduate courses for the general practitioner; (*f*) the organization of a clinical surgical fracture society, meeting once a year for the discussion of fracture problems.

In Fordham Hospital, the perfect harmony existing between the general and the orthopedic surgeon has shown the benefits that can be derived from such a procedure. Fractures are under the supervision of the general surgeons, but they often ask the advice of the ortho-

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2. Ollerenshaw: The Hospital Treatment of Fractures, Brit. M. J. **1**:559 (April 16) 1921.

3. Scudder, C. L.: Treatment of Fractures, Philadelphia, W. B. Saunders Company, 1922; Certain Problems Concerning Fractures of Bone, Ann. Surg. **74**:280 (Sept.) 1921.

pedists. Thus, all serious fractures, as spine, comminuted or bad compound fractures, are seen by the director of the service. He usually refers them to the orthopedist for further suggestions as to treatment and particularly for proper retention apparatus. The orthopedist in turn discusses the case with the general surgeon.

It often happens that a fracture has been properly reduced by the general surgeon but the fragments have slipped. The fault, of course, is in the retention, and he calls in the orthopedist for help. Thus the patient, the intern, the general surgeon and the orthopedic surgeon have the benefit of mutual help. This is particularly true of open bone work.

Undoubtedly, in the future there will develop a class of surgeons who will make fractures their chief interest, though this is not entirely desirable.

Following is a general outline of some orthopedic methods that are of value to the general practitioner, most of which have been accepted by surgeons in the Bronx hospitals.

EARLIER METHODS OF TREATMENT

Of the formulas taught by our predecessors, most are obsolete or should be discarded. The new textbooks on fractures emphasize in their prospectuses that old methods have been replaced by new ones.

These old formulas are: 1. A fracture should not be set before the swelling has subsided. 2. A fracture should be reduced by direct pull. 3. There should be immobilization as far as possible of the joints above and below the break. 4. Straight splints should be applied on a limb despite the fact that the limb is round. 5. Immobilization of bone and joints should be secured by bandages left in place until firm union has occurred. 6. The soft parts, skin, nerves, vessels and muscles may be allowed to take care of themselves.

We shall later on demonstrate that the foregoing formulas are based on false principles and cannot give the best results. The new methods are founded on sound principles and much better results are obtained.

The old methods of retention by means of bass-wood splints, Buck's extension, Liston splints, adhesive plaster dressing for fractured clavicle, etc., need only to be mentioned to call to mind the frequent failure of these contrivances after the fracture has been reduced as indicated by the roentgen ray. Of course, the problem of how to retain a fracture of the humerus, or femur, of a new-born infant or a nursling was doubly hard.

The duration of immobilization used to be from six to eight weeks, and it was hoped that by that time the bones were solid and would not slip; and then, if the surgeon was progressive, he ordered massage or rather rubbing and exercises.

The results, as you well remember, were poor function or marked delay in return of function, sometimes as long as one year. Union was either weak or the callus was so abundant that it could be seen at a distance. This callus alone often acted as a barrier to free motion of the joint, or there were nerves and muscles entangled in it. The shape of the limb was often so changed as to make a real deformity, which acted as a barrier to employment.

The use of the roentgen ray was employed only for the purpose of making sure there was a fracture; that the fracture had been reduced and that alinement was fair. In many fractures, a roentgen-ray examination was not made at all.

This, in general, constituted the treatment in most fractures.

MODERN DEMANDS OF END-RESULTS OF FRACTURES [4]

Fractures are increasing in number all the time, because of the increase of accidents by automobiles, especially in large cities, and the increase in the number of industries which expose workers to injuries. These two main causes put great responsibilities on us for the reason that in accidents not only does the public demand perfect results, since the reward allowed by the compensation or trial juries depends on that, but it also demands from us prediction of the results. To do justice, we are often asked to give the rate of disability. In compensation cases, the end-results treated by one method are so different from those of another that not only must the decision be different, but also the entire future of the workman depends on it. If a workman remains somewhat crippled, he cannot get employment, as the employer fears that an employee so afflicted might be frequently injured, and his compensation insurance rates be thus raised. Thus, even the slightly disabled person often becomes a burden to the family and to society.

The duration of time of treatment is also, at present, a more difficult question than before, as the economic condition of the middle class or the poor class requires early return to work. Even when the insurance companies pay compensation for the injured employee, he receives only two thirds of his salary after two weeks. This expense, of course, is afterward thrown on the product, and is thus paid by the consumer and by the employee involved.

It is also more important at present than previously to reduce the time of confinement to bed. The home conditions (even among the rich) prevent too long confinement. The hospitals are usually overcrowded, and as a great many fractures demand confinement to

4. In the January, 1923, issue of THE ARCHIVES OF SURGERY is published the outline of treatment of fractures as adopted at a special conference at Boston in April, 1922, by general and orthopedic surgeons. The article is extremely valuable to those interested in fractures.

bed, it is of paramount importance to employ the methods which shorten the stay in bed in each individual case.

As to the demands of the public for roentgen-ray examination in fractures, Hey-Groves [5] cleverly states: "It is now universally recognized in the law courts and by the lay mind that an X-ray record should form a part of the routine treatment of every bone injury, and in the face of this it would be folly to do otherwise than act on this view, which, after all, is the common sense one. The X-ray should be taken before the reduction but, if it can be managed, the patient should not be shown the X-ray."

To summarize the modern demands as to end-results, we agree with the practical suggestions of Bucholz or Moorhead. Bucholz [6] justly says: "The old dogma, 'Normal function depends on correct reduction of the fragments,' needs a modification at least for many kinds of fractures. We should rather say, 'Correct reduction of the fragments is one of the most important conditions, but by no means the only one, for the recovery of good function, and in many cases other factors may play a rôle so great that reduction becomes even of secondary value.' At any rate, the anatomical problem should never overshadow the functional problem, but, on the contrary, every step of the treatment must be directed toward a good recovery of the function."

The end-results as stated by Moorhead [7] can best be judged by three elements: (1) function; (2) union, and (3) contour.

Restoration of function is the most important item. This should be the main object of treatment. It is apparent that the profession at large does not as yet appreciate its full value. Function denotes the capacity to perform. Of course, this varies in different people, and we must recognize that fact beforehand. For example, the upper extremity is primarily related to such coordinated acts as the function ("sense") of grasp, of pull, of push, of touch. An artist is much concerned over the loss of sense of "grasp and touch," while the workingman is concerned over the loss of "push and pull."

Union denotes the state of repair of the injured part.

Contour denotes the external appearance of the injured part. In some patients, looks based upon the results of "union and contour" are of more importance than the restoration of function. The laity, unfortunately, generally regards union and contour as the main

5. Hey-Groves, E. W.: On Modern Methods of Treating Fractures, New York, William Wood and Company, 1922.

6. Bucholz, C. H.: Therapeutic Exercise and Massage, Philadelphia, Lea & Febiger, 1912.

7. Moorhead, J. J.: Measuring End-Results After Injury, a Suggested Percentage Basis, J. A. M. A. **79**:824 (Sept. 2) 1922.

elements; while the important item is really the function. Suits for malpractice are frequently the outcome when such an interpretation of an end-result prevails, notably in fractures in which, unjustly, the roentgenologic result is considered rather than the clinical or functional result.

To recapitulate, the success of treatment should be judged by return of function, the condition of union, the contour or external appearance, the duration of time under treatment and the duration of time of confinement to bed.

Having enumerated the fallacies of the old methods and having indicated the demands of the present, we can now take up the modern or orthopedic methods of treatment and make a comparison. We will be able to show that they overcome the difficulties arising from the old teachings and meet the requirements outlined.

THE MODERN METHODS

1. *Time of Reduction.*—It has been shown by Sir Robert Jones, Speed, Hey-Groves, Ashhurst and others that the best time for reducing is immediately after the accident, for the swelling usually increases if the fracture is left unreduced. Ashhurst,[8] in an editorial dealing with the prognosis of fractures, states: "The more promptly reduction of the fragments is secured, the easier it will be to obtain anatomical reposition. Especially is this true in joint fractures and in children. If attempts at reduction are delayed until swelling of the soft parts has reached its maximum, or until it begins to subside, they are not apt to be successful, and the mere fact that the broken bone has been restored to its normal form is very frequently enough to prevent injurious swelling of the soft parts from developing." If the fragments remain unreduced, the jagged ends of the bones will cause damage to the muscles and increase the swelling. Besides, the reduction is much more difficult, because of increased muscular spasm. Some adhesions are also formed and organization of the hematoma takes place even within forty-eight hours, and in a late reduction, these have to be torn. It is therefore advisable to reduce the fractures as quickly as possible. When the lesion is evident, it may be permissible to reduce it at once without a roentgenogram, though, as mentioned before, it is advisable and safer for the protection of the surgeon himself to take a roentgenogram. If it can be arranged for, it should be developed quickly and one should not wait twenty-four hours for the result.

2. *Methods of Reduction.*—It is best to reduce the fracture under anesthesia, as the muscular spasm is relaxed. It is also performed under the fluoroscope, where one sees the fragments and thus often

8. Ashhurst, A. P. C.: The Prognosis of Fractures, editorial, Surg. Gynec. & Obst. **35**:661 (Nov.) 1922.

sees where the interference to reduction lies. Later on, we shall discuss the procedure of reducing a fracture under the fluoroscope.

The old method of reducing every fracture by direct pull or extension in a straight line is mechanically wrong, since, when the fragments are overlapping, the muscles running in the same direction are naturally put in spasm and thus the difficulties are increased. Of course, after prolonged pulling, the spasm may be relieved, as the muscles tire, but usually the surgeon does not keep up the traction long enough. He tires more quickly than the muscle. It is much better to put the limb in position to take the pull off the muscles. The best examples of the difference in reduction are in fractures of the lower end of the radius and of the middle of the femur. There should be no fast rule for all fractures, but each fracture should be treated or reduced according to the correct muscle pull. We shall demonstrate this. Take, for example, the old method of treating the fracture of the middle of the femur by direct pull in a straight line with the knee fully extended. By that method, the hamstrings were put in spasm and reduction was prevented. The new method is to flex the hip and knee, thus overcoming the action of the hamstring muscles; and then to pull the lower fragment in line of the flexed knee. After reduction, the limb is put on a Thomas splint or plaster cast with the knee and hip flexed. The second example, fracture of the lower end of the radius (Colles' fracture) cannot always be satisfactorily reduced by the method of "hand shake." Sir Robert Jones,[9] in his excellent book, "Injuries to Joints," says in this connection: "The traditional method of reduction, by taking a grip of the hands as if shaking hands, still appears in text-books. It is quite inefficient in any stubborn case, for it is mechanically impossible to try to replace a small fragment like the detached lower end of the radius by traction and manipulation through a chain of small bones like the metacarpus and carpus through their ligaments." The grip Sir Robert Jones uses is as follows: "The surgeon takes the patient's arm in his left hand with his own tubercle against the projecting lower end of the shaft; he then places his right hand on the dorsum of the patient's wrist with his own scaphoid on the projecting lower fragment. A firm grip with a slight traction and twist of the wrist completely reduces the deformity. It requires knack rather than strength."

We can cite many more examples, but it is not necessary. Suffice it to say that no fast rule should be made. One must take into consideration the action of the muscles and relaxation in certain positions, and the fragments can often be more easily reduced. Under the fluoroscope, this can easily be demonstrated.

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9. Jones, Robert: Injuries to Joints, Oxford War Premiers, 1915.

The syllabus [10] which we have mentioned above summarizes the important facts concerning reduction as follows:

(*a*) Reduction of any existing displacement should be made as soon after the injury as possible, without waiting too many hours for the roentgen-ray examination.

(*b*) Reduction should be made as gently as possible.

(*c*) Reduction should be as complete as the individual case requires.

(*d*) Reduction may be controlled by fluoroscopic examination in appropriate cases.

(*e*) Reduction should be checked by a roentgen-ray examination as soon as practical.

(*f*) Manipulation should be carried out under an anesthetic with but few exceptions.

(*g*) Further attempts at reduction should be made as soon as the need is recognized.

3. *Means of Retention.*—We must emphasize that the method used for immobilization is merely to maintain immobilization and not reduction. Whether we use plaster or a splint, it acts only as a box to retain the limb in the proper position attained at the time of reduction. In most of the fractures excepting, perhaps, those of the shaft of the femur, the fracture can be reduced and will not be displaced any more if put in proper position to prevent muscular pull.

As for material used for retention, a plaster cast, i. e., a circular cast, is the best. It holds the limb well and prevents mucle spasm. If it is applied properly, there will be no pressure sores. The mistake is often made of employing too much padding, with the result that the cast does not fit well. One cannot put a straight splint on a round limb; hence, a posterior molded splint cannot hold well. Wooden splints (basswood) are still less desirable. A circular cast can be split into two halves in a few days and thus be used for a removable splint. One half can be discarded and the second half can be used to retain the reduction (Figs. 10 and 11).

The other retentive methods are the Thomas splints for the arm and leg and the Jones cock-up splint. The application of these is so simple, as proved by the work of the special splint squads in the war, that every general practitioner should find no difficulty in mastering their application. One can hold almost any fracture with these splints. They can be used at any age. We have used them even in a birth fracture, in infants a few hours old.

The other splints in use at present are the Balkan frame, whose application is rather difficult, and the Bradford frame, used for spine

10. Outline of Treatment of Fractures, Arch. Surg. **6**:172 (Jan.) 1923.

fractures. The inherent value of any apparatus is of less importance than the skill with which it is used.

4. *Duration of Time of Immobilization.*—The earlier teaching was to leave the limb immobilized till firm union was apparently attained. The bandages were usually applied so firmly as not to permit shifting of the fragments during the whole period required for consolidation, which was estimated at between two or three months. Hey-Groves [5] thus points out the fallacy of this teaching: "This principle is liable to be futile or dangerous; it is futile if the bandaging be not really firm, and dangerous if it be. The fixation of the bone is obtained at the expense of the soft parts, the nutrition of which will suffer in proportion to the tightness of the bandage and the completeness of the immobilization. There is, therefore, a complete negligence of the soft parts, muscles, vessels, nerves and joints." The new method is to begin treatments within a few days. Bucholz [6] treats some fractures even on the second day. The means of retention can be so arranged that the fragments are not disturbed when massage is given. For instance, if a Thomas splint is used, the massage is given on the bandage. If a circular cast is used, it can be split in half in such a manner that when one half is taken off the other can retain the fragments (Figs. 10 and 11). After ten days, each half can be taken off during massage. Of course, one has to be trained in the handling of the limb during the massage so as not to dislodge the parts or cause pain, especially when the callus is still soft. As emphasized before, it is the muscular spasm that keeps the muscles apart and will have a tendency to displace them. If, however, the fracture has been reduced and the splints are applied so as to relax the muscles, there is little fear of dislodging them during massage. Proper massage has also the beneficial effect of relaxing the muscles in spasm. In the third week, the splints in some fractures, such as those of the lower end of the radius, can be left off altogether. In others, it is kept on till about the fifth or sixth week. The first retentive apparatus is often changed for a simpler one after a short time. One must keep in mind that repair is more rapid in cancellous than in cortical bone.

5. *After-Treatment of Fractures.*—To hasten the union, to obtain proper union as well as good and early return of function of the limb, we are using the following adjutants: (*a*) Baking. The active hyperemia produced by the baking (dry heat) in really good baking machines (not mere lamps) causes a local increase of arterial blood, an absorption of exudate and an increase of new cells, which, in the case of bones, are the osteogenetic cells. The pain is markedly reduced by this means. One can also use daily local baths in hot water and Epsom salt, when the splint or casts can be temporarily removed. We begin the baking

in most cases (if no splint is applied) on the fifth day. It is given in the beginning every day; then, every other day.

(*b*) Massage. This term, or rather this part of the treatment, is often and too much abused. As too often applied, the massage treatment of fractures consists, first, in splinting a fracture for days or weeks until early union has occurred, thereby producing stiffness of muscles and joints. Then a professional masseur is called in to give a daily "rubbing." The limb is punched and pummelled and the joints are moved with more or less force; and the greater the pain caused, the greater the good the massage is supposed to be doing. It may well be doubted whether such a treatment advances recovery by a single day; in fact, it often positively retards it.

As it ought to be practiced, the method consists in applying a gentle superficial stroking, a soothing caress, to the injured part at the very outset. Such treatment must relieve muscular spasm and not cause pain.

Massage as applied to fractures is applied not directly over the swollen area but at the periphery. One can easily hold the fragments with one hand or on one half of the plaster and use the other hand. In the first few days, the duration of massage should be very short, only three to four minutes, to absorb the hematoma. Later on, it is increased. Massage is usually administered after the baking.

To demonstrate the method of massage and retention we shall consider a common fracture, that of the lower end of the radius (Colles' fracture). As soon as possible, the fracture is reduced and a plaster cast is applied, extending from the elbow to the knuckles. We usually put on two pieces of felt, one at the dorsal aspect of the lower fragment, and one at the anterior aspect of the upper fragment, to hold the fragments better. Three days later, the cast is cut in half in such a manner as to prevent slipping. The dorsal half is taken off and baking is given. For the massage, the forearm, with the anterior half, rests on the masseuse's left hand, while with the right hand she massages the muscles of the forearm, using gentle stroking, kneading and rolling manipulations for three or four minutes. Then, a few gentle slow passive movements of each finger individually are carried out. The splint is reapplied and bandaged.

This treatment is repeated daily, adding every day one minute of massage, up to ten minutes, and a few movements of the fingers, up to ten or fifteen. Gradually, the massage is to include the tendons, hand and fingers. On the tenth day, the anterior half of the splint can be removed and the forearm kept on the masseuse's left hand. Thus, both sides can be massaged. Flexion of the wrist can be used if the operator encircles the fractured area with the index finger and thumb. It usually happens that on the fifteenth day motion of the

fingers is almost completely restored, and even the mobility of the wrist and forearm is improved to a certain extent. One half of the splint can then be left off. At the end of four or five weeks, only a wrist band of felt and adhesive plaster should be used.

(*c*) Exercises. Contrary to the old custom, we begin exercise very early, but do not leave this to the patient himself or to the parents, but instruct our masseuse very carefully as to how this is to be carried out. It is best to begin with active exercises. Later on, resistance exercises are used. If slight adhesions have formed after five or six weeks, passive exercises are to be given, but these should not be very vigorous. Exercises favor the formation of callus. If properly given they cause no pain, but, on the contrary, alleviate it. They cause no pseudoarthrosis. The exercises also shape the callus by allowing the tendons to play freely and normally over the soft callus. They thus prevent adhesions later on.

One must always keep in mind what the final result should be in each limb and aim for that; e. g., the lower limb is used for standing, hence all the energy should be directed toward a straight knee. The upper extremity is used for work; hence, the elbow should be in a flexed position, if one cannot get a real functioning and free elbow. The shoulder should be in an abducted position as much as possible, in order that one may have fair use of that limb.

(*d*) Occupational therapy; function. As mentioned before, the results of a fracture are at present judged by the function. Occupational therapy can therefore be resorted to with great advantage. We allow a patient to return early to his work, hoping that the muscles which the patient needs for performing his work can be made to function early and properly. Of course, this form of exercise is more interesting for the patient, as has been proved, in general, by the benefits derived.

DIFFERENCE BETWEEN THE TWO METHODS

OLD METHODS	MODERN METHODS
1. Reduction of the fracture after the swelling has subsided.	1. Immediate reduction of the fracture.
2. Reduction of the fracture by direct pull.	2. Reduction of the fracture in accordance with relaxation of muscular pull.
3. Immobilization as far as possible of the joints above and below the break.	3. Immobilization to prevent slipping by the muscular spasm, irrespective of whether another joint is to be included or not. Usually only one joint has to be included.
4. Application of straight splints though the limbs are usually round.	4. Application of plaster cast or splint with proper regard to the shape of the limb.

5. Securing of immobilization of bone and joints by bandages left in place until firm union has occurred.	5. Immobilization allowed for a short time only, till one is positive that the fragments will not slip; then other treatment is employed.
6. Allowing the soft parts (skin, nerves, vessels and muscles) to take care of themselves.	6. Proper care of the soft parts by early massage and exercises and removing the splints early.
7. Contour or union in good position the main aim.	7. Function the main aim.
8. Prolonged confinement to bed.	8. Very early return to function.
9. Correction of deformity later on if it occurred during the treatment. It is often considered inevitable.	9. Prevention of deformity very carefully watched.
10. Roentgen ray used only once or twice during the entire time.	10. Roentgen ray used much more frequently.

OPERATIVE METHODS

Cases are frequently seen in which, in spite of any method employed, the fracture has not been reduced or union has not begun. In such cases, open operations become an absolute necessity.

"Operative treatment is indicated when a satisfactory reduction cannot be obtained by nonoperative methods, provided there is no contraindication, and when the expected result of the open method is sufficiently better than that of the closed to justify the additional risk. Furthermore, it is generally recognized and accepted that, in certain types of fractures, it is impossible to obtain satisfactory restitution except by operative methods." [10]

Instead of Lane plates or wiring, the modern methods of bone graft have found a distinct and useful field. It would be out of place to discuss here the indications for operative interference and methods of bone grafting.

INTERPRETATION OF RESULTS

At present, owing to the compensation laws and the frequent legal complications of accidents, and also to the entanglements of the war risk insurance, we are often called on for an exact and detailed report of the disabilities and the exact prediction of the outcome of the accident. The old terms "good," "fair," "poor" or "bad" are inadequate, as they are too vague, and what one surgeon calls fair, the other will call "absolutely bad." The sex and occupation of the patient often comes into consideration: what for a workman will be an excellent result will be considered bad for a violin player.

Moorhead [7] is therefore justified in measuring the end-results on a percentage basis. Taking the three elements of the result: function, union and contour, he arbitrarily allows 60 per cent. for function, 20

per cent. for union and 20 per cent. for contour. While in some cases, the contour may be of more importance than the apportioned 20 per cent. would indicate, it cannot be really considered the most important item of the three. If function is three-fourths perfect, we allow three fourths of 60 per cent. or 45 per cent.; if union is one-half, we allow one half or 10 per cent.; if contour is one-fourth perfect, we allow one-fourth of 20 per cent. or 5 per cent. So our result is the sum of 45 plus 10 plus 5 per cent., giving 60 per cent. as a result. If contour is of importance, one can give it a little higher rating, subtracting this percentage from function. If we wish to bring these descriptive numerical terms in line with our former use of words, we can say that a result of 80 + is good; 60 +, fair; 40 +, poor, and 20 +, bad.

One can often, by this method, make a pretreatment estimate of the condition and then be able to report whether there is improvement or not.

The function as well as the contour has very often to be more exactly reported than in former years. Thus, we record the angle of extreme motion in terms of degrees or present it graphically on charts. To measure the angles of motion of a joint, different forms of "goniometers" have been invented. While not all of them are perfect, most seem to serve the purpose fairly well. The common ones in use are, Thoele's universal caliper, Virchow's cephalometer, Bertillon's caliper, Miller's dactylometer and Bott's goniometer.

The graphic charting of Nutter has been found useful in our work. The angle of the joint as well as the limit of voluntary and passive motion are taken by Bott's or another satisfactory apparatus, so that the exact angle in degrees is noted. This is recorded on a chart which has a rough diagram of a man with the joint in neutral position. The limits of motion are indicated in dotted lines.[11]

For measuring the length, a tape measure should be employed, and not just a glance of the eye. Exact and fixed points are chosen. For the lower extremities, we have employed the letters used in the Hospital for Ruptured and Crippled for a long time, and have found them absolutely reliable: RA, distance from right anterior superior spinous process to internal malleolus; LA, distance from left anterior superior spinous process to internal malleolus; RU, distance from umbilicus to right internal malleolus; LU, distance from umbilicus to right internal malleolus; RT [6], circumference of right thigh taken at a definite point above the lower border of patella, here, 6 inches (15 cm.); LT,[6] circumference of left thigh; RK, circumference of right knee; LK circumference of left knee; RC, circumference of right calf at the bulkiest

11. Nutter, J. G.: Reconstructive Surgery, J. A. M. A. **72**:410 (Feb. 8) 1919; Standardization of Joint Records, J. Orthop. Surg. **1**:423 (July) 1919.

point; LC, circumference of left calf at the bulkiest point; for the upper extremities; RAM_5, right arm at a definite point below acromion process; LAM_5, left arm at a definite point below acromion process; RFM_3, right forearm at a definite point below olecranon process; LFM_3, left forearm at a definite point below olecranon process.

For measuring the power of the hand, the monometer is used which records in terms of pounds. Normally, the power of the right hand is from 50 to 60 pounds; that of the left hand, from 40 to 50 pounds. Of course, this varies in different individuals. It may be worth while since we speak so often of the right and left side, to emphasize that these words should be underlined on the history sheet so that one may not write "left" when he really means the right side.

These, in short, are the methods of measuring and recording results. One may consult the "fracture chart" prepared by the Fracture Committee of the American Surgical Society to see how the different methods are compared. We are accustomed to use the following outline in charting results.

FRACTURES

History No..... Special Fracture No. (Case No.).....

1. Name..... Age..... Occup..... Address.....
   Nat.....M. F.....W. C.....S. M. W.....Photo No.....
   X-ray Nos..... Date of adm.....
2. Date and Time of Injury.....
3. Cause of Fracture:
   Direct violence .....
   Indirect violence .....
4. Bone affected..... Limb..... Part.....
5. Type of Fracture:
   Simple .....
   Compound .....
   Transverse .....
   Oblique .....
   Spiral .....
   Comminuted .....
6. Deformity:
   In long axis.....
   Transverse axis .....
   Shortening .....
7. Character of Line of Fracture:
   From examination .....
   From X-ray plates.....
   From operation .....
8. Previous Treatment .....
9. Method of Reduction:
   (*a*) Time instituted .....
   (*b*) Anesthesia or not.....
   (*c*) Flouroscope .....

10. Closed Method:
    (*a*) Manipulation .....
    (*b*) Splints.....Kind (Bucks, Blakes, Jones, Steinman)
    (*c*) Brace .....
    (*d*) Plaster of paris.....
    (*e*) Traction .....
11. Open Method:
    (*a*) Immediate or delayed operation.....
    (*b*) Simply for reduction or nonunion.....
    (*c*) Wire .....
    (*d*) Plates .....Kind
    (*e*) Bone Transplant.....Method
    (*f*) Nails .....
12. Amount of Shortening:
    (*a*) First dressing.....
    (*b*) When all apparatus were removed.....
    (*c*) At latest observation (date).....
    (State how measurements were taken)
13. After Treatment: Frequency Duration Time Begun
    1. Thermotherapy
    2. Massage
    3. Active motion
    4. Passive motion
    5. Occupational therapy
14. Result:
    (*a*) Function .....
    (*b*) Contour .....
    (*c*) Union .....
15. X-Ray Findings:
    (*a*) Before reduction or operation.....
    (*b*) Immediately after reduction.....
    (*c*) When all fixations are removed.....
    (Note condition of bone)
16. Social and Economic Conditions:
    (*a*) Length of time in bed.....
    (*b*) Length of time absent from work.....
    (*c*) Length of time crutches, canes or other aids to walking were used.....
    (*d*) Is patient able to take his former job?.....
17. Disability at Last Observation Estimated by:
    (*a*) Deformity .....
    (*b*) Endurance .....
    (*c*) Pain .....
    (*d*) Swelling .....
    (*e*) Interference with joint function.....
18. Special:
    (*a*) Carrel-Dakin Solution .....
    Complication .....
19. Mortality:
    (*a*) Cause of death.....
    (*b*) Date .....

COMMON FRACTURES ILLUSTRATING MODERN METHODS [12]

1. *Fracture of Clavicle.*—Hodge [13] uses a T-board with a figure of eight around both shoulders, which we have found very satisfactory. The patient can thus use both hands while union takes place. Massage can be started on the second day.

2. *Fracture of Neck of Humerus (Anatomic and Surgical).*—The upper extremity is put in marked abduction at right angles with the torso and rotated outward. This gives the best result; as an adducted arm can be used very little. The shoulder can be immobilized in that position in a Thomas Jones abduction airoplane splint or a plaster spica. Massage can be started on the seventh day, active motion in the second week.

3. *Fractures of Upper Thirds and Mid-Thirds of Shaft of Humerus (Above Insertion of Deltoid).*—A hinged Thomas arm splint or Jones humerus splint is employed, and the arm can be left at the side (though we prefer abduction). Massage is begun after seven days and active motion in two or three weeks. The splint can be changed for a sling about the fifth or sixth week.

4. *Fractures of Lower Third of Shaft of Humerus.*—The arm is put in a Jones humerus splint or a circular cast, and is suspended or kept at the side. Massage is begun at the end of the first week and active motion at the end of the second week.

5. *Supracondylar or Fractures of Condyle or a T-Fracture into the Joint.*—These require more details than can be here given.

6. *Fractures Around Elbow Joint.*—Sir Robert Jones emphasizes that, with the exception of fractures of the olecranon process, in all fractures around the elbow the joint should be put in acute flexion. Immobilization by means of plaster of Paris can easily be applied. Massage is begun in five days; active exercises in seven days. In fracture of the olecranon process, the arm is put in full extension.

7. *Fracture of Forearm.*—If the fracture is above the attachment of the pronator radii teres, the cast extends to the middle of the arm from the wrist joint. The forearm is in supination. The elbow is flexed at right angles. If the fracture is below the attachment of the radii teres, the plaster cast extends from the knuckles to the elbow joint, which may be included, flexed at right angle, with the forearm in position of pronation or midpronation. A piece of felt must be placed between the two forearm bones to prevent cross union. Massage is begun on the fifth day; active exercises are started on the seventh day.

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12. I am giving only a general outline of the most common fractures. For details, one should consult the modern textbook. The fracture outline gives in detail the different fractures.

13. Hodge, R. L.: A Simple Splint for the Treatment of Fractures of the Clavicle, J. Orthop. Surg. **1**:439 (July) 1919.

8. *Fractures of the Lower End of Radius (Colles' Fracture).*—The traditional method of reduction, by taking a grip of the hand as if shaking hands, has been shown by Sir Robert Jones to be wrong. Jones' method, previously described, should be employed. The fragments can be retained in position by plaster casts. Usually, two pads of felt are put on, one on the dorsal aspect of the lower fragment and one over the palmar aspect of the upper fragment. Massage is begun on the third or fifth day, exercises on the eighth day. The plaster can be changed to a wrist band at the end of the second week or in the middle of the third.

9. *Fractures of Carpal Bones.*—The hand should be put up in hyperextension, as the hand can be most useful in that position. This can be done in a plaster-of-Paris cast, or a Jones cock-up splint. Baking, massage and active exercises should be begun on the fifth day.

10. *Fractures of Spine.*—There should be immediate immobilization in a Bradford frame or a plaster jacket even if the roentgen ray does not reveal an extensive fracture. Immobilization should be continued for a long time.

11. *Fracture of Pelvis.*—This is best treated by tight swathes, or webbing belts, sometimes by plaster spicas. These alarming fractures usually heal well and quickly and are less serious than is generally feared. The patient may be kept supine for four weeks.

12. *Fracture of Neck of Femur.*—This should be treated by Whitman's abduction method. Age is no contraindication. While the limb can be held in a double Thomas Jones' splint, the plaster cast is much more satisfactory. The plaster is changed for a caliper and crutches about the sixth month. No weight bearing is allowed for five months. Massage can be begun at the end of the third month, and active exercises at the same time.

13. *Fracture of Shaft of Femur.*—This is best treated with Thomas Jones' splint, with flexion of knee and hip. Even infants can be treated by this splint (as has been shown in a previous article [14]). Massage can be started early, but walking should be delayed until the end of the third month, as this bone, in the process of walking, bears the entire weight of the body during one half of the time and will easily bend, and cause marked interference. Active motion is begun at the end of the first month.

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14. Boorstein, S. W.: Treatment of Birth Fractures at Fordham Hospital, Am. J. Dis. Child. **19**:375-383 (May) 1920.

14. *Fractures Around Knee Joint (Supracondylar or T-Fracture into Knee Joint).*—These are difficult fractures to treat and cannot be discussed in a short article. They often require an open operation.

15. *Fractures of Tibia and Fibula.*—Immobilization up to the knee, with the ankle joint flexed dorsally at right angles, usually suffices. We can permit walking very early, even at the end of the first week. It is important to get good alinement of the tibia, as both knee and ankle joints are hinge joints and a good line is important. Massage is begun on the third or fifth day, active motion at the end of second week.

16. *Fracture of Patella with Separation of Fragments.*—This often requires operation. One may try for eight days full extension of the knee in a Cabot splint or plaster cast with felt pads above and below the patella to approximate the fragments. A caliper splint is used in the second month. Massage is begun immediately if possible and active motion as soon as the skin wound is healed.

17. *Fracture of Patella Without Separation.*—The limb is put in a circular cast, a Cabot splint or a Thomas Jones splint. Massage is begun on the third day, active motion at the end of the first week.

18. *Fractures Around the Ankle Joint.*—One must keep in mind that to have a good function, the foot must be at right angles to the leg. In complicated Pott's fracture, when this position cannot be obtained, one should cut the Achilles tendon in order to pull down the os calcis (Dowd [15]). During the time that the bone unites, the Achilles tendon will unite. Massage is begun on the fifth day, active motion at the end of the second week.

The subjoined cases serve to illustrate that the functional result is the most important consideration, and we should not depend entirely on the roentgenologic findings.

REPORT OF CASES

CASE 1.—M. O., a woman, aged 59, recommended by Dr. H. Hershberg, suffered a fracture of the surgical neck of the humerus (Fig. 1), which was reduced under anesthesia and the arm put in a plaster cast in marked abduction. The roentgen ray (Fig. 2) after reduction showed slight impaction. Massage was begun two weeks later. There was a good result in three months (Fig. 3).

CASE 2.—J. A., a woman, aged 48, recommended by Dr. Raabe, had a comminuted fracture of the shaft of the humerus, which was reduced under anesthesia, though the fragments were not in a good anatomic position (Fig. 4). Baking and massage were begun after ten days. The result was very good and there was good union (Figs. 5 and 6).

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15. Dowd, C. N.: Lengthening of the Tendo Achillis in the Treatment of Complicated Pott's Fracture, Ann. Surg. **68**:330 (Sept.) 1918.

Fig. 1 (Case 1).—Fracture of surgical neck of humerus before reduction.

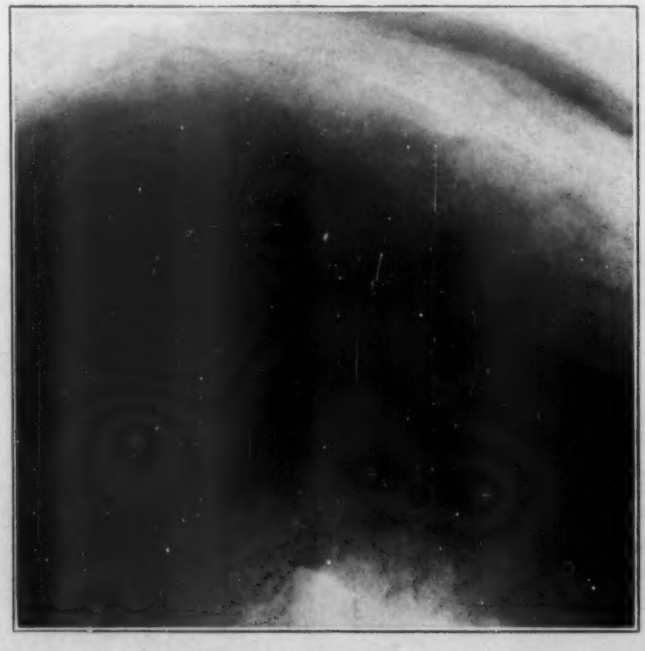

Fig. 2 (Case 1).—Fracture of surgical neck of humerus after reduction. Abduction was obtained but the fragment is not fully reduced.

Fig. 3 (Case 1).—Three months after treatments, showing good union. Patient has very good use of the shoulder.

Fig. 4 (Case 2).—Comminuted fracture of the humerus. The postion obtained in the plaster may be noted. One would be inclined to operate in this case.

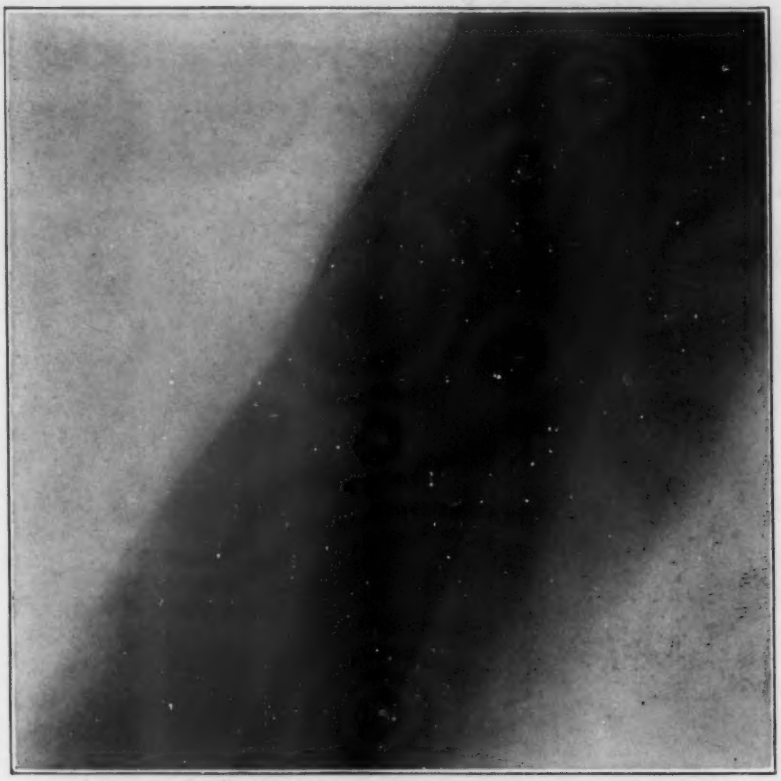

Fig. 5 (Case 2).—Fracture of humerus; appearance four months after the accident. The good position and the callus formation may be noted.

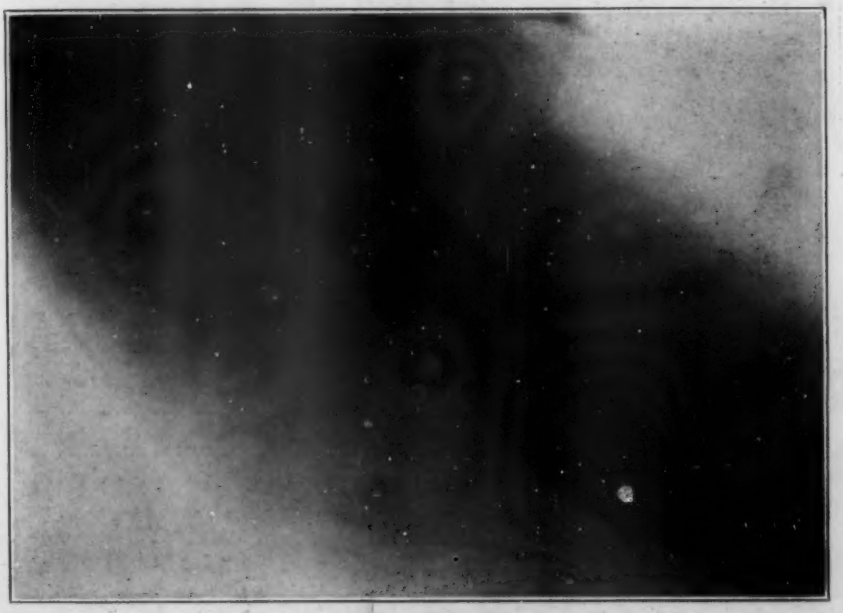

Fig. 6 (Case 2).—The final result: good union and a proper amount of callus.

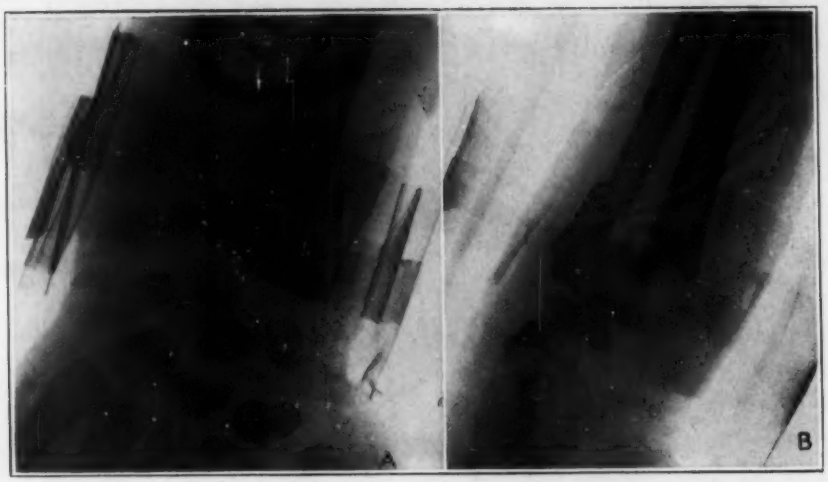

Fig. 7 (Case 3).—Fracture of lower end of radius and ulna; displacement of lower fragment of radius backward and inward; *A*, anterior-posterior view, *B*, lateral view.

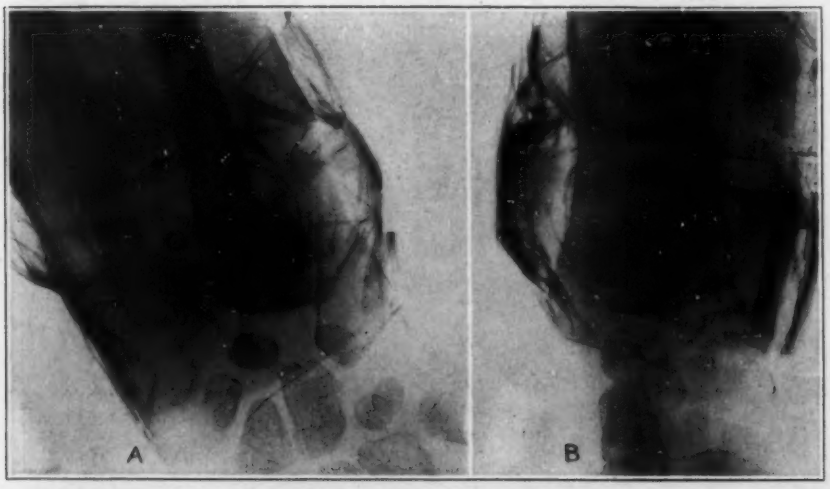

Fig. 8 (Case 3).—Slight improvement in position after several attempts at reduction. There is still an overlapping in the anteroposterior position; *A*, anteroposterior position, *B*, lateral view.

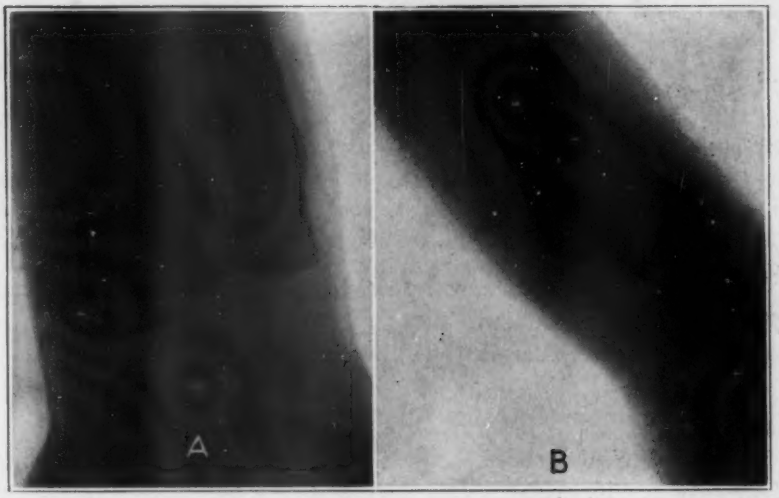

Fig. 9 (Case 3).—Four months after treatments, showing good union and better position. Function was perfect. Two and a half years after discharge, there is no deformity or interference with growth; *A*, anteroposterior view, *B*, lateral view.

Fig. 10.—Bivalved cast for the forearm.

Fig. 11.—Bivalved cast for the leg.

CASE 3.—M. L., a boy, aged 6, recommended by Dr. Burstan, had a fracture of the lower end of the radius and ulna, with displacement of the lower fragments (Fig. 7). Two attempts were made by one of us (S. W. B.) to get a good position, but failed. An effort to get the lower fragments into a slight angle (Fig. 8) was successful. Baking and massage were begun on the fifth day. Gradually, the massage shaped the bone so that the final functional result was perfect. The contour also was good though the last roentgen-ray examination revealed a slight deformity (Fig. 9).

These cases do not demonstrate that one should neglect to obtain a good anatomic reposition, but show that frequently if the after treatment is carefully carried out, the final result will be good.

CONCLUSIONS

1. Proper attention should be paid to treatment of fractures, as better and quicker results are now expected.

2. Each fracture should be treated as a problem by itself, with the final aim of restoring good function.

3. Early reduction is absolutely necessary.

4. Reduction should be performed with full consideration of muscle pull and not according to the traditional custom of pulling by direct extension.

5. When possible, the fracture should be reduced under the fluoroscope.

6. Restoration of anatomic position should be the aim, but partial lateral displacement or impaction without alteration of the axis of the limb is allowed.

7. Retention should be planned according to the muscle pull and not according to the old rule that the joints above and below the break should be encased.

8. Straight splints should not be used on round limbs.

9. The retention apparatus should be as simple as possible and made "fool proof." It must be so arranged that no displacement takes place during the healing. It must be properly put on.

10. Prolonged immobilization is harmful.

11. Massage should be commenced very early, about the third or fifth day; but it must be administered very carefully and gently in the hands of an experienced masseuse and not by a plain "rubber."

12. The exercises prescribed should be definite, not haphazard; i. e., simply instruction to the patient to exercise.

13. Active exercises are preferable to passive. These should be commenced early, as they prevent stiffness and adhesions. They never cause pseudoarthrosis.

14. Passive exercises may be justified only at the end of the treatments to obtain full range of motion, but even these should be done gently.

15. A roentgenogram should be taken before and immediately after reduction, and at frequent intervals during the course of treatment. The patient should not be discharged without a final roentgen-ray examination.

16. The end-results should be judged according to the function, contour and union, and not according to the roentgenographic readings.

17. The end-results should be reported accurately, and not by the general terms good, fair, poor and bad.

18. Interns in the hospital should receive proper training in the treatment of fractures just as well as in the practice of general surgery, so as to prepare them for this important work.

ROENTGENOLOGIC ASPECT

The extent of information furnished by the roentgenologist to the surgeon in his treatment of fractures is so great and so obvious that no one now even begins to treat a fracture without his aid.

While it is true that perhaps a fair percentage of cases need no roentgen-ray information for their proper treatment, still even minor juxta-articular bone injuries result disastrously under the best of treatment; hence, the rule of taking roentgenograms in all fractures or suspected fractures.

Some surgeons have stated that it is not necessary to take a roentgenogram at once, but to wait for some time after reduction to determine the final result. The fallacy of such a method is obvious. If it should become necessary to take a roentgenogram during the course of the treatment, it may then be too late to benefit the patient.

As to whether the reduction of fractures should wait on a roentgenographic examination, this is a mooted question. It appears to be the latest teaching that fractures should be reduced and immobilized at once, then examined by roentgen ray to determine the position obtained. The ideal mode of procedure obviously is to take a roentgenogram immediately after the fracture to determine its nature; then to reduce the fracture, and finally to take a second roentgenogram, to note the character of reduction.

In tabulating some of the essential features in the matter of the roentgen-ray examination of fractures, the following should be borne in mind:

1. *Legal Aspect.*—The decision of the courts is all too familiar to require elaboration. It is held that the absence of a roentgen-ray

examination in a fracture is, per se, basis for a malpractice suit, and recovery of substantial damages is the rule in such neglect.

2. *Suspected Fractures.*—Roentgenograms must be made in sprains about the joints to determine their true nature. "Sprains," under the old meaning of the term, simply included all ligamentous injuries. But a careful study of the roentgen plates has shown that a sprain is frequently accompanied by a laceration of the periosteum, and a fracture of a small piece of the cortex of the bone.

3. *Nature of Fracture.*—A determination as to whether it is comminuted, incomplete, transverse, oblique, spiral, etc., is valuable to the surgeon in determining his mode of correction.

4. *Position of Fragments.*—This is determined with reference (*a*) each to the other; (*b*) to the surrounding structures; (*c*) to the structures interposed between the fragments; (*d*) to loose fragments, in the case of comminuted fractures, which may require removal before proper reduction can be attempted; (*e*) to intra-articular fractures. When the joint has been involved, correct reduction is very important. Small fragments of a comminution may require prompt removal to insure a perfect functioning of the joint.

5. *Epiphyseal Fractures.*—In fractures in which only a laceration of the growing epiphysis is noted, with no displacement, the roentgenologist should, as a matter of routine, in view of the importance of this condition, examine the corresponding normal joint for comparison. Frequently, to the inexperienced eye, the multiplicity of epiphyses about a joint may confuse.

6. *Pathologic Fractures.*—Fractures are often caused by a relatively slight injury, and the roentgen-ray examination will determine the underlying pathologic condition, which in itself may necessitate other forms of treatment: (*a*) bone cysts; (*b*) sarcomas; (*c*) metastatic carcinoma, which may be the first indication of the disease without finding the primary lesion; (*d*) myeloma, etc.

7. *Differential Diagnosis.*—Fractures are to be differentiated from (1) scurvy; (2) rickets; (3) osteomyelitis, and (4) arthritic conditions.

8. *Extent of Union.*—Reexamination of the fracture from time to time will often furnish information as to union, and in cases of delayed union, other methods of procedure should be instituted before it is too late. Progress of callus formation can be determined by careful inspection of the osteogenetic layer. If complete bony union has not occurred, and the osteogenetic layer is still present, there is still hope for complete bony union. If, however, no union is present, and there is an absence of the osteogenetic layer, some other means of obtaining

bony union must be resorted to. The extent of the callus can be determined, as to whether it is normal, subnormal or excessive, and, in the case of the last, as to whether the callus is interfering with the joint and involving pressure on the nerves.

9. *Compound Fractures.*—Roentgenograms are made to determine the extent of bone disease (periostitis or osteomyelitis), if present. In order to note the progress of this bone disease, the roentgen examination is important as to determining further procedure.

10. *Reexamination.*—Immediately after reduction, reexamination is important, to determine whether the fragments have been brought into fairly good apposition. But it should be borne in mind that an examination a week or two after the reduction is also of great importance, to determine whether the immobilization has been effective. This is especially true of fractures of the shafts of the long bones, in which the fragments frequently slip past each other, after perfect reduction has seemingly been accomplished.

11. *Atrophy of Bone from Disuse.*—The extent and nature of atrophy can be determined only by roentgen-ray examination.

12. *Operative Reduction.*—In bone grafts, etc., the roentgen ray is indispensable.

13. *Technic.*—An elaborate discussion is too technical for so short a space. Suffice it to say that all fractures should be examined in two planes (the normal planes are preferable) at right angles to each other. If the examination is made obliquely, it should be so stated to the attending surgeon. In several fractures, especially those about the ankle, oblique views are necessary; and again in other parts of the body, as the hip and shoulder, when views in two planes are not feasible, stereoscopic examinations are in order.

14. *Fluoroscope.*—Diagnosis of fracture should not be attempted by this method, as fissure fractures, sprain fractures, incomplete and subperiosteal fractures would often be overlooked. Reduction under the fluoroscope, however, is coming more and more into vogue. A roentgenogram should be made to determine the nature of the fracture, which should then be reduced under the fluoroscope. Lastly, another roentgenogram should be taken in order to note the result. Incidentally, the last roentgenogram would be positive evidence, legally, of institution of proper treatment.

15. *Reporting of Fractures.*—In reporting the character of a fracture, the roentgenologist and surgeon should bear in mind that a good functional and then a good cosmetic result are the objects sought after, and that perfect alinement of the fragments is not necessary to obtain this desired end. Therefore, when the roentgenologist reports "no dis-

placement of fragments," even if there is an apparently slight displacement, one should take his word for it and leave well enough alone.

16. *Portable Apparatus.*—Portable roentgen-ray machines are so well developed today that in the matter of fractures just as good a roentgenogram can be made at the bedside as in a fully equipped laboratory.

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SUPPURATIVE TENOSYNOVITIS OF THE FLEXOR MUSCLES OF THE HAND*

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On account of their economic importance and surgical interest, a study of the acute infections of the flexor tendon sheaths of the hand was undertaken at the Presbyterian Hospital over two years ago. A series of fifty-seven consecutive cases, observed from Jan. 1, 1916, to Jan. 1, 1923, has been analyzed. The series is presented, with the end-result in each case, observed for an average time of nearly one and one half years. These end-results are defined so that the reader may appreciate what have been considered as various degrees of success or failure. The method of treatment presented has been evolved as a result of lessons learned by experience. By means of a definite technic, to be described subsequently, we have been able to achieve far better results in our later cases than in our earlier ones.

Suppurative tenosynovitis of the flexor tendons of the hand may be divided into two main groups or subdivisions which differ considerably in their physical findings and clinical course, and, indeed, in the end-results obtained. A definition and description of each of these groups is essential before proceeding. They will be designated as the primary and secondary groups.

A primary tendon sheath infection is one in which there is a direct implantation of the invading organism into the sheath, at the time of the original injury or shortly thereafter, by means of the original wound.

A secondary sheath infection is one in which the sheath has been invaded from a surrounding area of infection, such as an improperly drained abscess overlying the sheath or adjacent to it, or from a distant focus of infection. The surgeon's knife may open and infect an uncontaminated sheath by a badly placed incision in attempting to drain a superficial infection of the finger. The sheath is occasionally invaded from the blood stream, as, for example, in two cases of gonorrheal tenosynovitis in this series.

In this series of fifty-seven cases, of which thirty-three are primary and twenty-four secondary, the two groups will be frequently contrasted and compared.

There is usually a trauma preceding the infection, although certain cases, such as those of gonorrheal origin, may show none. Some injury was described in 86 per cent. of our series. Of these injuries, the most frequent was a punctured wound (63 per cent.), and in two thirds

* Read at a meeting of the Surgical Section of the New York Academy of Medicine.

of these was a foreign body, such as a wooden or steel splinter or a piece of needle. Incised wounds, with an occasional inadvertent incision into the sheath, were next in frequency, and abrasions and contusions followed. In three cases, the injury was a human bite. These infections, due to the micro-organisms on the teeth and in the mouths of human beings, usually follow a bite, which may allow direct invasion of the sheath; or a cut on the knuckles, from which the sheath is invaded secondarily. The wound of entrance is small, and drainage is soon sealed off by dried exudate. The infection spreads, killing all tissue down to and including bone. The odor is foul. Baking and soaking cause the process to extend with greater rapidity. The sheath

Fig. 1 (Case 12, A. N., 1921).—A primary hemolytic streptococcus infection of the sheath of the little finger, spreading to the ulnar bursa above the annular ligaments, to the radial bursa and sheath of the flexor longus pollicis. The portal of entry was at the distal crease of little finger. The patient came to the hospital five days after onset, during which time she had been under the care of her family physician, who made a small incision in the little finger on the day of admission. The swelling was so enormous that classic signs were masked. The little finger and ulnar bursa were drained first, the radial bursa and sheath of thumb were opened the following day. The annular ligament was split two weeks later, but this procedure was too late to save the tendons, the majority of which sloughed. The culture of pus at the last operation showed hemolytic Staphylococcus aureus—a secondary contamination of the wound. A much better result might have been obtained with more radical incisions from the beginning, and revised technic. The patient was unable to try active motion. Photographs show bad end-result sixteen months after operation. A badly crippled hand with slight flexion at metacarpophalangeal joints of all except the little finger. The thumb can be opposed to all except the little finger. The patient was able to pick up small objects and to write.

invasion is usually followed by osteomyelitis, and amputation may become necessary. We recommend in these cases immediate wide débridement.

WOUND OF ENTRANCE

The tendon sheath is reinforced over the proximal and middle phalanges by a very dense and tough digital vaginal ligament, which is attached to the margins of these two phalanges. Such strong bands, if situated at the interphalangeal joints and at the metacarpal phalangeal joint, would seriously interfere with flexion; therefore, at these points, there are weaker and more delicate transverse bands known as the annular ligaments. The soft parts overlying the sheaths are thinnest at these creases or skin joints. From these anatomic facts, one would expect to find the sheaths most often entered by wounds at the creases. Investigation has shown beyond shadow of doubt that this is the case in the primary tendon sheath infections. The point was not especially noted prior to 1920, but of all the primary cases in the series, nearly 60 per cent. had wounds at the digital flexion crease, with the distal crease involved in 70 per cent. of them. Since 1921, this point has been carefully noted in every case, and 100 per cent. of the thirteen primary cases have shown a wound at a digital flexion crease. The secondary group did not show flexion crease wounds. The sheath was invaded, probably through its unprotected portion, from abscesses of the distal, middle or proximal anterior closed spaces (in order of frequency); from palmar abscesses and web infections, and in two cases from an abscess of the dorsal surface of the finger. Incompletely drained anterior closed space infection is the most frequent cause of this secondary group of flexor sheath infections.

TIME ELEMENT

The average primary case came to operation three days and sixteen hours after the injury was sustained; whereas, in the average secondary case, there was a delay of a little over fifteen days. In the earliest case seen the patient was admitted to the hospital with the classic symptoms and signs of tenosynovitis, seven hours after running a splinter into the distal flexion crease. Another case came to the hospital within nine hours.

SYMPTOMS AND PHYSICAL SIGNS

In order of importance, the symptoms and physical signs are: (1) tenderness along the sheath; (2) position of flexion with inability actively to extend the finger; (3) passive extension of the terminal phalanx, causing exquisite pain. In addition, the patient complains of severe throbbing pain along the sheath, increasing to a point where sleep

is impossible. There may or may not be high fever, chills and malaise. This classic picture of tissue under tension due to exudate within the sheath is most frequently encountered in the primary case. The careful elicitation of varying degrees of tenderness by beginning with gentle pressure over a normal adjacent area and then approaching the sheath is most helpful in arriving at a diagnosis. There is usually no tenderness in the distal closed space. An abscess in the palm or in the proximal anterior closed space may be ruled out by tenderness in the middle anterior closed space. The finger should always be supported in the most comfortable position during the examination. In two cases, in which swelling due to exudate or edema became enormous, especially

Fig. 2 (Case 14, F. M., 1921).—A primary hemolytic streptococcus infection of the sheath of the middle finger. The portal of entry was at the middle flexion crease. The finger was treated with revised technic and active motion. The condition was complicated by severe cellulitis of the dorsal surface of the hand, requiring incisions. The immediate result was a little flexion in all the finger joints, but the end-result was bad—a stiff flexed finger without any motion in the interphalangeal joints. This end-result was in some part due to a chronic arthritis of all finger joints, as shown in Figure 3. The bad end-result eighteen months after operation is shown.

beneath the annular ligament, classic tenderness was masked. This may have been due to pressure on the ulnar and the median nerves. A partially drained sheath fails to show these symptoms and signs; which accounts for the failure of most of the secondary group to present the classic picture.

DIAGNOSIS

In this series, the condition was recognized on first appearance of the patient in 75 per cent. of all cases. In the primary group, the correct diagnosis was made in 82 per cent. Five quite frank primary cases that should have been recognized were not diagnosed for two or three days. Recognition of but 58 per cent. of the secondary group calls for improvement in diagnosis.

HAND OR FINGER INVOLVED

In 73 per cent. of the cases, the right hand was involved nearly three times as often as the left, and the fingers whose sheaths were most frequently invaded are those used most often in grasping: the thumb and the index and middle fingers.

EXTENSIONS OF PUS FOUND AT OPERATION FOR SUPPURATIVE TENOSYNOVITIS

In thirty-four of the fifty-seven cases, the pus was confined to the digital sheath. In those cases in which the pus extended beyond the confines of the sheath, a consideration of the paths traversed and the areas subsequently involved is interesting.

Radial and Ulnar Bursae.—The digital sheath of the flexor pollicis longus muscle was infected eleven times. In three of these cases, there was no extension above the annular ligament. Whether these three cases were confined to the digital sheath and did not invade the radial bursa cannot be definitely stated. If it is assumed that these are digital sheath infections, the percentage corresponds to the percentage of cases in which, according to other authors, the digital sheath is separated from its corresponding radial bursa. In eight cases, the pus extended above the annular ligament. In only three of these eight radial bursa cases was the ulnar bursa and sheath of the little finger invaded.

The sheath of the little finger was invaded seven times, and in four cases infection was confined to the digital portion. All three ulnar bursa infections extended above the annular ligament, but only one showed extension to the radial bursa and sheath of the flexor pollicis longus.

All three of the infections of the thumb sheath which remained localized to the digit were secondary, and three of four of the little finger sheath infections remaining localized were secondary. The only secondary cases to spread above the annular ligament were two infections of the sheath of the flexor pollicis longus.

This suggests that the secondary group of sheath infections extends slowly, 75 per cent. of this secondary group of infections of the thumb and little finger being confined to the digital portion of the sheath. There seems to be time for the sheath to protect itself against the

invading organism. Since 72 per cent. of the infections of the sheath of the thumb extended to the radial bursa, while only 42 per cent. of the little finger sheath infections invaded the ulnar bursa (the number of primary and secondary cases in each being approximately equal),

Fig. 3 (Case 14).—Appearance of finger joints, due in part to a chronic arthritis.

one may be justified in assuming that the radial bursa is easier of access to the organism invading it from its digital sheath than is the ulnar bursa. The anatomic continuity between the radial and ulnar bursae above the annular ligament is open to question. In numerous careful

searches for this continuity in the dissecting room, neither Auchincloss nor I have been able to demonstrate it. The invasion of pus from one of these bursae to the other has taken place in four of ten possible cases, or 40 per cent. We have seen the radial bursa filled with pus and the ulnar bursa free five times; the radial bursa free and the ulnar bursa pus-filled, once. The extension may be explained by the contiguity fully as well as by the continuity of these sacs.

Palmar and Dorsal Extensions.—In four cases, the thenar space was invaded, each time from the sheath of the index finger. The mid-palmar space was invaded twice from the sheath of the ring finger. The web between the index and middle fingers was invaded four

Fig. 4 (Case 16, F. F., 1922).—A primary hemolytic streptococcus suppurative tenosynovitis of the flexor pollicis longus and flexors to the little finger. The portal of entry was at the proximal crease of the thumb. From the sheath of the thumb, the infection spread to the radial bursa, the ulnar bursa and the little finger sheath. The space in front of the pronator quadratus was filled with pus. The hand was widely drained the fourth day after onset, and healing was uneventful. Revised technic and active motion were employed. Photographs show a good end-result nine months after operation. Function in thumb is 75 degrees of normal, with good active flexion at the metacarpophalangeal and interphalangeal joints. The condition of the little finger is less satisfactory, but there is some active flexion in both interphalangeal joints.

times through the lumbrical canal from the index sheath, and once from the middle finger. The web between the ring and middle fingers was invaded twice from the middle finger sheath through the lumbrical canal.

Pus was seen in the dorsal subcutaneous tissue either at the time of operation or subsequently in five cases, the spread being apparently through the web. The dorsal subaponeurotic space was invaded once through the metacarpophalangeal joint.

One secondary case spread from the dorsum of the hand to the index finger sheath and thenar space, apparently through the web between the index and middle fingers. This infection followed a cut on the knuckles from an opponent's teeth, and resulted in the loss of the finger.

Fig. 5 (Case 19, H. A., 1922).—A primary Staphylococcus aureus tenosynovitis of the index finger, the portal of entry being at the distal flexion crease. The condition was unrecognized for two days in the outpatient department. The finger was operated on four days after onset. The condition was complicated by a tremendous sloughing beneath the distal flexion crease, where more adequate drainage should have been provided. Revised technic was used with active motion. Photographs show a good end-result six months after operation, with 60 per cent flexion at proximal interphalangeal joint and 15 degrees at distal. The atrophy following the sloughing of the soft parts may be noted.

The neglected secondary cases of long standing showed the most extensive areas of suppuration. In one of these cases, the patient came to us two and one-half months after a wound on the little finger, with multiple incisions, pus in the midpalmar and thenar spaces, the ulnar

bursa destroyed, pus in front of the pronator quadratus and an osteomyelitis of both radius and ulna.

Another of these, following an index finger infection of one month's duration, presented pus in the thenar space, the midpalmar space and the space in front of the pronator quadratus.

One primary case, the only fatality, in which the pus spread early and rapidly into the forearm, was carefully observed. The sheath of the thumb was invaded, and the infection spread to the radial bursa and then to the ulnar bursa and sheath of the little finger. From the space in front of the pronator quadratus, the pus traveled up the forearm to the intermuscular planes, in front of the interosseous membrane, behind the flexor sublimis and profundus digitorum muscles,

Fig. 6 (Case 17, M. W., 1922).—A primary hemolytic streptococcus infection of the sheath of middle finger which came to operation four days after onset. The portal of entry was at the distal flexion crease. Revised technic was employed with active motion. The wounds healed uneventfully. Photographs show a fairly good end-result four months after operation, with 50 degrees of flexion at the metacarpophalangeal joint and a slight amount of active flexion at both interphalangeal joints. A good fist can be made and the usefulness of the hand is very little impaired.

along the median nerve and its vessels. Extensive pockets of pus were then found between the brachioradialis, the biceps and the brachialis muscles.

CLASSIFICATION OF END-RESULTS

Fifty-six of the fifty-seven cases have been followed for an average time of nearly fifteen months. The follow-up notes have been dictated by eight or ten surgeons, whose opinions naturally vary. All results

have been estimated from an anatomic, symptomatic and economic standpoint, and an optimum result should rank high under each of these headings. In defining our results, we have used function as the main criterion; but the anatomic condition might be used as the gage. This anatomic basis is very important in subsequent plastic repair. A functionally useless finger in good anatomic condition is often very suitable for tenoplastic work.

Our end-results have been divided into the following four groups. The frankly optimum and equally frankly bad results fall easily into

Fig. 7 (Case 5, J. H., 1916).—A primary hemolytic streptococcus tenosynovitis of the flexors to the little finger invading the ulnar bursa in the palm but not above the annular ligament. The wound was adequately drained thirty hours after onset. The optimum end-result nine months after operation is shown.

their respective groups, but classification of other results is more difficult. There are some borderline cases which lie somewhere between good and fair or between fair and bad. We have tried not to overestimate a result in any case.

1. Bad results: (*a*) Death; (*b*) amputation; (*c*) deformed, stiff, painful finger, without motion at the interphalangeal joints and little if any at the metacarpophalangeal joint.

2. Fair results: Almost complete motion at metacarpophalangeal joint but no active motion at the interphalangeal joints. The finger is not necessarily deformed, and a fist may be made with the aid of the other fingers.

3. Good results: Complete function at metacarpophalangeal joint and some slight active motion in the interphalangeal joints. A fist is readily made, actively for the most part, though adjoining fingers may aid in producing extreme flexion.

4. Optimum results: An almost complete return of normal function in the finger. There may be some limitation of extreme flexion, but the finger is practically as useful as before the infection.

BACTERIOLOGY

In studying the bacteriology of this infection, an attempt has been made to determine the relation, if any, which the various micro-organisms bear to the healing of the wound and the end-results obtained. Forty-eight of the fifty-seven cases were cultured, and in forty-one of these, micro-organisms were recovered. *Streptococcus hemolyticus* was found at operation in pure culture in twenty-five cases (60 per cent.), and *Staphylococcus aureus* in pure culture in five cases, or 13 per cent. In the remaining 27 per cent., there was a mixture of various types of streptococci and staphylococci. *Streptococcus hemolyticus* was recovered from the blood of one patient who died of sepsis following a very virulent cellulitis of the entire upper extremity. A study of the bacteriologic findings (Table 1) reveals the following facts:

The hemolytic streptococcus cases usually showed little discharge from the wounds. Sloughing of the subcutaneous tissues and tendons occurred in 33 per cent. of the cases. Osteomyelitis was present in 23 per cent. of the cases. The end-results were good or optimum in 28 per cent. and bad in 42 per cent.

The hemolytic streptococcus cases secondarily contaminated form an interesting group. There were four of these cases definitely proved, and two others should probably be included but cultural evidence is lacking. One of these patients was discharged from the ward with wounds almost healed and was subsequently contaminated in the outpatient department. The other three were contaminated during the course of their ward treatment. In all of this group, careless technic was manifest. The end-results in two of these cases were very bad, one coming to amputation and the other ending with a badly crippled hand, most of the tendons having sloughed. The two other cases which probably belong within the group each had unsatisfactory results. This definite proof of contamination of infected

TABLE 1.—*Bacteriologic Findings*

Organism	Total Number	Number of Cases	Wound Healing: Amount of Exudate: Large	Moderate	Small	Sloughing: Subcutaneous: Absent	Subcutaneous: Present	Tendons: Absent	Tendons: Present	Osteomyelitis: Absent	Osteomyelitis: Present	Results: Bad	Fair	Good	Optimum
Hemolytic streptococcus	21	15 primary	0	4	11	13	2	13	2	14	1	4	6	2	3
		6 secondary	2	2	2	1	5	1	5	2	4	5	..	..	1
Hemolytic streptococcus secondarily contaminated with Staphylococcus aureus	4	4 primary	4	0	0	1	3	1	3	3	1	2	..	1	1
Nonhemolytic streptococcus	2	2 primary	1	0	1	2	0	2	0	2	0	..	..	1	1
Streptococcus of various types, with staphylococcus "mixed infection"	8	4 primary	0	1	3	4	0	3	1	3	1	2	1	..	1
		4 secondary	3	1	0	1	3	1	3	2	2	2	1	..	1
Staphylococcus aureus	5	3 primary	2	0	1	0	3	3	0	3	0	..	..	2	1
		2 secondary	2	0	0	0	2	1	1	1	1	1	..	1	..
Staphylococcus albus	1	1 primary	1	0	0	0	1	0	1	0	1	1	..	..	..

tendon sheaths with disastrous results led us to change our postoperative care of all tendon sheath infections to a technic to be described in detail under treatment.

The staphylococcus infections showed more profuse discharge and sloughing of the subcutaneous tissues. The tendons sloughed in only one case, however. Osteomyelitis was present in one case. The end-results were unexpectedly good, four of five being rated good or optimum, and only one result considered bad.

Fig. 8 (Case 8, J. B., 1920).—A secondary tenosynovitis of the sheath of the ring finger following an abscess in the web between the ring and little fingers. The patient came to hospital fifteen days after the original injury. A culture of the pus was sterile. The sheath was drained in the proximal anterior closed space. The optimum end-result with normal function twenty-five months after operation is shown.

The primary mixed infections showed little discharge and little tendency to sloughing, and osteomyelitis was present in only one case. The results were bad or fair in three of four cases. The secondary cases of mixed infections had profuse discharge, sloughing of subcutaneous tissues and tendons and osteomyelitis in three cases. Three

of four of these were rated bad or fair. This group has the poorest record, 75 per cent. of unsatisfactory results.

The two cases of nonhemolytic streptococcus had no sloughing or osteomyelitis. The results were good in one and optimum in the other. It is noteworthy that profuse discharge, sloughing of both tendons and subcutaneous tissues and osteomyelitis were more frequently associated with the secondary than with the primary group.

Gonococcus Tenosynovitis.—The infections of the tendon sheaths due to the gonococcus differ so materially from those due to other micro-organisms and form such a distinct and contrasting group that,

Fig. 9 (Case 9, H. M., 1920).—A primary hemolytic Staphylococcus aureus infection of sheath of index finger. The portal of entry is in the distal flexion crease. The patient was operated on forty-eight hours after onset. Two subsequent operations were performed to give more adequate drainage, but the patient eventually got an optimum end-result with almost complete flexion in all joints. The end-results twenty-six months after operation are shown.

although there are but two cases in our series, it seems worth while to describe them in a little more detail.

One patient (Case 22) sustained a contusion of the palm of the left hand, following which the shoulder was lame, and then pain, tenderness and swelling developed along the course of the sheath of the ring finger. Eight days after the injury, he came to the hospital with symptoms and signs severe enough to indicate the necessity of draining the sheath. The sheath was found to contain a few drops of

pus, from which nothing grew on culture; but a smear showed a few very definite gram-negative intracellular diplococci. The patient had been suffering from gonorrhea. The temperature fell abruptly from 105 to below 100 F. on the second day after operation. The tenosynovitis improved. Prostatic massage and irrigations caused the posterior urethritis to subside. The patient was discharged from the hospital on the fourteenth day after operation, with very good function. The latest follow-up note, three months after operation, shows an almost complete return of function in the ring finger.

The second patient (Case 23) without a history of trauma came to the hospital three days after the onset of his illness. The left ring

Fig. 10 (Case 10, E. B., 1921).—A secondary tenosynovitis of sheath of flexors to the middle finger following an abscess over the palmar portion of sheath, coming to hospital seven days after the onset of the abscess. A small amount of pus was found in the sheath. There was active motion immediately after operation. Optimum end-result with practically complete function in the finger fifteen months after operation is shown.

finger suddenly became painful and swollen. It was very tender; was held in flexion, and the slightest flexion or extension caused excruciating pain. At operation, a considerable amount of cloudy fluid was found within the sheath, from which nothing was grown on culture. The patient had had attacks of gonorrhea eight and four years previously and an epididymitis three weeks prior to the present illness. Following operation, the patient developed successively attacks of fever with pain and swelling in both ankle joints, wrist joints, great toe and

right shoulder; and definite signs of tenosynovitis in other fingers of the same hand. A urethral smear following prostatic massage showed gram-negative intracellular diplococci. The patient remained in the hospital for two and one half months, during which he received prostatic massage, gonococcus vaccines and baking. The subsequent attacks of tenosynovitis were treated without incision. The function of the hand on his leaving the hospital was excellent.

The results in both these cases were practically 100 per cent. recovery of function. Those sheaths which were not drained did fully

Fig. 11 (Case 13, E. M., 1921).—A primary hemolytic streptococcus infection of sheath of flexor pollicis longus, of four days' duration. The portal of entry was at the distal flexion crease. The pus spread above the annular ligament to the space in front of the pronator quadratus. This space was subsequently opened more widely the third day after operation. A culture taken then showed a contamination with Staphylococcus aureus. This case marked the beginning of the use of revised technic which was instituted after the second operation. A great deal of credit for the excellent result must be given to the patient for his tireless effort and unusual courage in early active motion of the thumb. Photographs show the optimum end-result five months after operation. Unfortunately, the thumb was not taken in full extension, a position which was freely attained.

as well as those which were. It is quite fair to raise the question whether this type of tenosynovitis would not always yield to expectant treatment, such as immobilization and traction, with the proper measures applied to any urethral or prostatic focus of infection. One might recommend this procedure did not failure to incise and drain suppurative tenosynovitis early and adequately in those cases due to the streptococcus, staphylococcus, etc., lead to such bad results that, in cases of doubt, it is advisable to risk an unnecessary incision.

TREATMENT

Early incision, accurately located, is the first principle of treatment. The operative procedure should be planned to drain adequately the sheath and any adjoining collections of pus, if these exist. The digital incisions have been for the most part anterolateral, either one or two in each closed space, the middle and proximal spaces most frequently. When single incisions are used, they are generally alternated, as, for example, on the radial side in the middle closed space and on the ulnar side in the proximal space. These incisions should not be placed too far laterally in the closed spaces or the digital vessels and nerves will be divided. The numbness and atrophy which follow such a division are very distressing to the patient. When there is a good deal of subcutaneous pus and necrosis beneath a flexion crease, it is helpful to prolong one of the anterolateral incisions beyond the crease in order to secure adequate drainage. Small cross nicks or transverse incisions in the flexion creases connecting with the anterolateral incision are helpful in relieving tension.

The palmar portion of the sheath should be opened to its full extent by a long median longitudinal incision. The ulnar bursa is opened up to the annular ligament, keeping to the radial side of the deep branch of the ulnar nerve. In only one case was it found necessary to split the annular ligament, and it was then too late to save the tendons from sloughing. We believe there are cases in which the annular ligament should be entirely divided. The radial bursa or sheath of flexor longus pollicis in the palm is opened just to the ulnar side of the thenar eminence. Great caution should be observed lest this incision be continued too far proximally, and the branch from the median nerve to the thenar muscles thus be divided.

We have found delicate instruments absolutely indispensable in this type of surgery. A fine scalpel, small forceps and very tiny sharp and blunt retractors are used. A bloodless field is maintained by either an Esmarch bandage or a blood pressure cuff tourniquet. A careful anatomic dissection is then made, down to the tendon sheath. The sheath is opened with a tiny nick, and then the incision is extended

on a grooved director. With gentle pressure on the surrounding areas, all extensions of pus may be traced and adequately drained. If it is necessary to prolong the operation over forty minutes, the tourniquet is released and reapplied.

Collections of pus above the annular ligament in front of the pronator quadratus muscle are drained by lateral incisions, following closely the shaft of radius and ulna on either side, as described by Kanavel. Drainage of this space by means of volar incisions between the flexor tendons has not been so satisfactory. The drainage material has been for the most part what is called silk binding tape, the incision being packed open with rubber tissue or rubber dam. The rubber tissue or dam gives more bulk and holds the wounds more widely open. This

Fig. 12 (Case 15, R. A., 1921).—Suppurative tenosynovitis of flexor pollicis longus muscle. The portal of entry was at the distal flexion crease. A culture of the pus gave no growth. The space in front of the pronator quadratus was invaded, but there was no spread to the ulnar bursa. Revised technic was employed. The patient was unable to cooperate in early active motion. He showed a wrist drop thought to have been due to pressure neuritis of the radial (musculospiral) nerve from an Esmarch tourniquet used at operation. Photographs show an optimum result six months after operation, with almost complete flexion in thumb. Attention is called to the photograph to the right showing the thumb in three positions.

can be removed at the end of twenty-four hours, while the silk can be removed at the end of thirty-six or forty-eight hours, without bleeding. Prior to 1921, the drains were left in the wounds for an average of six days. During this same period, active motion in the finger was noted on the record in only ten of the thirty-one cases treated, and

the average time when it was first mentioned in these cases was the fifth day after operation. The usual treatment was by means of frequent sterile saline or boric solution drips, soaking or irrigation. Irrigations with surgical solution of chlorinated soda (Dakin's solution) by the Carrel technic, with rubber tubes in the wounds, was used in eight cases, with three good, three bad and two fair results. The one case terminating fatally in the series was treated by this method. Our experience has not justified the use of rubber tubes in the wounds, and we have therefore discarded this form of irrigation with surgical

Fig. 13 (Case 21, M. D., 1922).—A primary hemolytic streptococcus tenosynovitis of the ring finger, the portal of entry being the middle flexion crease. The patient was operated on two days after onset. Revised technic and active motion were employed. The wounds healed uneventfully. Photographs show an optimum end-result six months after operation, with almost normal function.

solution of chlorinated soda. Baking was used in the great majority of cases, often alternated with soaking or with drips.

Early in 1921, our attention was called to the possibility of contaminating these tendon sheath infections. Careless technic in dressing the wounds and the use of soaks of questionable sterility were among the most obvious causes of contamination, serving to counterbalance every

advantage gained by early diagnosis and adequate drainage. The following revised technic was instituted as routine in the treatment of these cases:

The hand and forearm at the time of operation are placed in sterile towels. Two or three hours later when all bleeding has stopped, the towels are removed and the hand is soaked continuously in a 4 per cent. sterile boric solution, with a temperature of 110 F., for twenty-four or thirty-six hours.

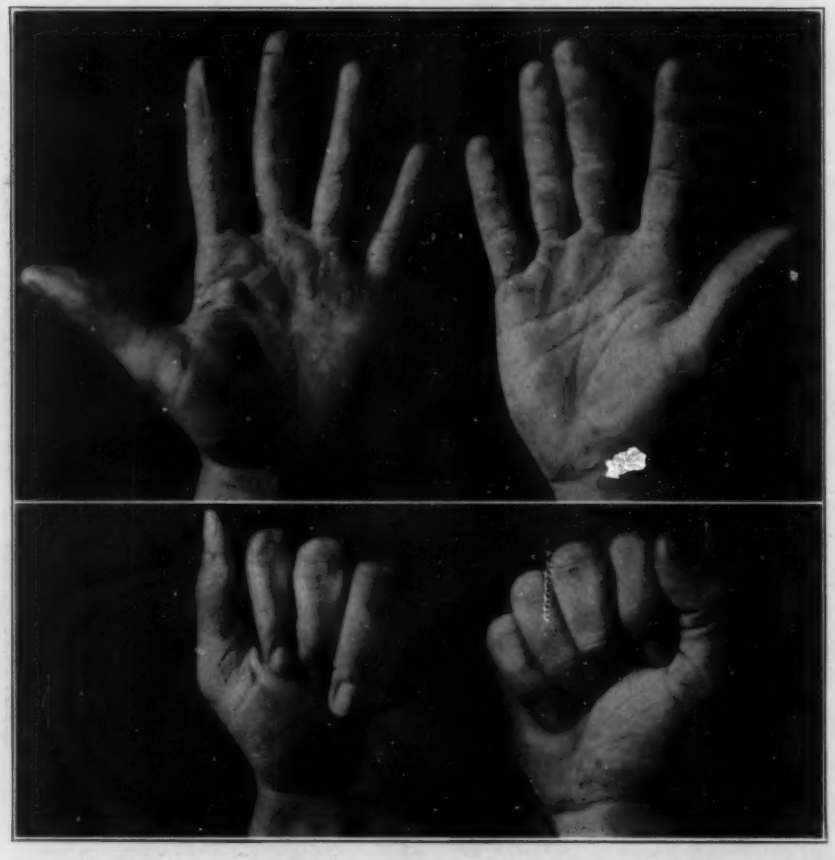

Fig. 14 (Case 23, J. B., 1922).—A secondary gonococcus tenosynovitis of the ring finger, operated on three days after onset. Revised technic and immediate active motion were employed. The wound healed uneventfully. Photographs show an optimum end-result with almost normal function, two and one-half months after operation.

This treatment adds very greatly to the patient's comfort, promotes drainage and facilitates active motion, which the patient is encouraged to try from the very beginning. The rubber-dam drains are removed at the end of from twenty-four to thirty-six hours; the hand is placed in sterile towels, and intermittent soaking in boric acid solution is instituted, one hour in and three

hours out. After each soaking, the wounds are irrigated with surgical solution of chlorinated soda by means of a fine capillary pipet. Baking is commenced four or five days after operation, three or four times a day for from twenty to forty minutes at a time, alternated with soaking. As healing progresses, the number of soakings is gradually diminished, until only baking is used. The time to stop the soaking varies, but the condition of the granulations is a very good indication. If they become pale and edematous, so-called water-logged, it is well to discontinue soaking. All drains are removed by the third day after operation.

During this regimen, the patient's hand and forearm are never touched except with sterile gloves or instruments. The frequent irrigations are carried out by those of the nursing staff who have

Fig. 15 (Case 24, R. S., 1922).—A primary Streptococcus viridans and Staphylococcus albus tenosynovitis of the middle finger, the portal of entry being at the distal flexion crease. The patient was operated on seven hours after onset, the earliest case of the series. Revised technic and immediate active motion were employed, the wound healing uneventfully. Optimum end-result with complete function, four months after operation, is shown.

been carefully trained in this technic; while the surgeon dresses the wounds at least once a day. Since the technic must be rigidly enforced, the surgeon cannot delegate responsibility, and hope to achieve good results.

This technic has been used in fifteen cases, five of which were secondary and ten primary, with optimum results in eight, good results in four and bad results in three cases. These figures indicate a 100 per cent. increase in our optimum results.

POSTOPERATIVE COURSE

A patient with a normal temperature five or six days after operation, with healing satisfactory without further operative procedure, has what we consider an uneventful postoperative course, and forty-two of the fifty-seven cases belong in this category. In eleven cases, although the postoperative course was not in any sense alarming from the patient's general condition, subsequent operations were necessary to provide adequate drainage.

Only two of our patients gave the surgeon occasion for grave alarm. Both were trained nurses, one of whom died. The first

Fig. 16 (Case 22, S. A., 1922).—A secondary gonococcus tenosynovitis of the left ring finger, operated on seven days after onset, the wound healing uneventfully. Revised technic and immediate active motion were employed. Photographs, taken three months after operation, show an optimum end-result, with almost normal function.

of these patients developed a suppurative tenosynovitis of the index finger following a paronychia and cellulitis of the distal anterior closed space. The infection, due to a particularly virulent hemolytic streptococcus, developed into a cellulitis of the entire upper extremity. Repeated blood cultures failed to reveal a streptococcus, but for weeks the patient had a high temperature from sepsis. Recovery followed amputation of the finger, and the patient was discharged on the fifty-third day after admission. The second case was a primary hemolytic

streptococcus infection of the sheaths of the thumb and little finger. The hand and fingers seemed to yield readily to drainage, but the infection spread with amazing rapidity up the forearm. Four operations were performed. The temperature remained between 101 and 103 F., and a hemolytic streptococcus bacteremia developed. Amputation of the arm had been decided on, when there was a sudden marked improvement in the patient's general condition. A few hours later, she died from what appeared to be a pulmonary embolism.

It should be noted that of the fourteen patients requiring secondary operations, nine had bad end-results, 64 per cent. as compared to 30 per cent. bad results among all the patients in the series. This fact is a significant indication of the importance of early and adequate drainage.

There were fifteen cases of osteomyelitis of the phalanges or metacarpal bones, with suppurative arthritis in a large percentage of these. One interesting complication was a paralysis of the musculospiral nerve, with consequent wrist drop. This disappeared entirely within three months after operation, and may very possibly have been due to compression neuritis from an Esmarch tourniquet.

END-RESULTS

A study of the end-results in fifty-seven cases summarized in Table 2, in connection with some of the factors influencing them is presented for consideration.

TABLE 2.—*End-Results as Regards Number of Cases*

	Primary		Secondary		Totals	
	No. of Cases	Percentage	No. of Cases	Percentage	No. of Cases	Percentage
Optimum	9	27	6	25	15	26+
Good	8	24	3	12.5	11	19+
Fair	10	30	4	16.6	14	25
Bad	6	18	11	45.8	17	30

1. Time from onset of injury or symptoms until the patient was operated on. Only 19 cases of the series came to the hospital within three days after the onset, and 47 per cent. of these got an optimum result, with 10 per cent. bad results. Of the thirty-eight cases coming to operation over three days after onset, 18 per cent. got optimum results, 40 per cent. bad. The average length of time for all optimum results was three days and fifteen hours; while the average time for all bad results was sixteen days. These facts emphasize the tremendous importance of the time element. The chance of getting a good result in a tendon sheath infection diminishes rapidly as time passes before operation.

2. Secondary and primary groups contrasted. A glance at Table 2 will show a striking contrast between the results in the primary and in the secondary groups. With 45.8 per cent. bad results and 25 per cent. optimum results in the secondary group, compared to 18 per cent. bad and 27 per cent. optimum results in the primary group, one can easily appreciate that the chance of getting a useful hand or finger is considerably better in the primary group. The secondary cases have usually come to the hospital after considerable treatment.

3. Previous treatment. In an attempt to discover the relation between end-results and treatment prior to admission to the hospital,

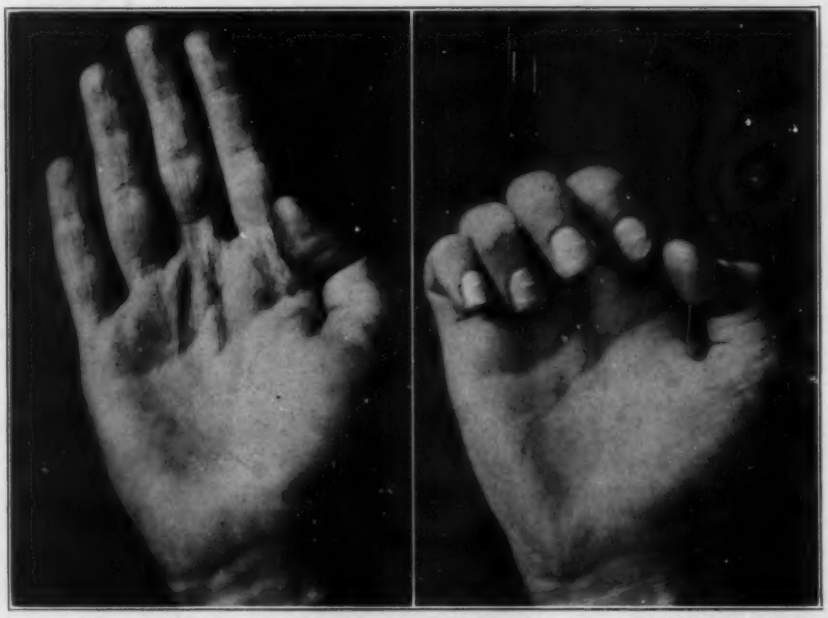

Fig. 17 (Case 25, A. W., 1922).—A secondary Staphylococcus aureus tenosynovitis of the middle finger following an abscess of the proximal anterior closed space. Definite symptoms developed and the condition was recognized immediately. The patient was operated on one day after onset of the sheath infection, revised technic and immediate active motion being employed, and the wound healing uneventfully. An optimum end-result, with almost complete return of function is shown four months after operation.

the patients have been divided into two groups. In one group are included all patients with previous surgical treatment, and in the other group, all patients without previous surgical treatment. There were thirty-one cases in the previously treated group, with 42 per cent. bad results and only 9 per cent. optimum results. The twenty-six surgically untreated cases had only 8 per cent. bad and 50 per cent.

optimum results, in marked contrast. The time element cannot however be disregarded, as the previously treated cases invariably arrived later at the hospital.

4. Micro-organisms. The staphylococcus cases showed a high percentage of good and optimum results. The cases with mixed staphylococcus and streptococcus recovered from pus at the time of operation had a high percentage of bad results, as did the cases secondarily contaminated and then presenting a similar mixed growth. The streptococcus cases with other factors favorable, such as time after onset, no previous treatment, etc., yielded some of the best results.

5. Postoperative treatment. To realize fully the important bearing this has upon end-results one has but to review the fact that, in the last fifteen cases treated by the revised technic, there were 53 per cent. optimum results and 78 per cent. good or better, a marked contrast to the similar percentage of the entire series. In addition to this scrupulous care in dressing, early removal of drains has been insisted on. The remaining factor in the postoperative treatment is early active motion. The patient is urged, at times driven, to move the finger immediately after operation. His cooperation is invaluable in this matter.

6. Chronic arthritis. This complication has been noted in two cases, and in both of them, a fair or good immediate result has been completely nullified, and the finger has become stiff and deformed. Many patients well past middle age show a tendency toward this condition, which is an unfavorable factor in an effort to obtain a good result (Case 4).

CONCLUSIONS

In the course of this series, we have studied the evidence presented by the individual case, endeavoring to learn something from each patient. At the end of every case on our summary sheets, we have drawn up a conclusion on that particular case, preparatory to reaching conclusions on the series as a whole. Every case offers something of interest, but certain facts stand out as common to many or to all of them. From these facts, we have drawn the following conclusions, which we present, not as preconceived theories or formulated ideas, but rather as a summary of amassed evidence.

1. The suppurative infections of the tendon sheaths fall naturally into two groups. The primary group, in which the infection is primarily that of the tendon sheath, usually gives the classic picture of tenosynovitis. In this group lies the greatest opportunity for obtaining good results by means of proper treatment. The secondary group, in which the sheath is usually invaded as an extension from some other

preexisting suppurative process in the hand or a distant focus, is frequently not recognized until late, and has a much less hopeful prognosis than the primary group.

2. The flexor tendon sheaths are most frequently infected from wounds at the digital flexion creases. Wounds at these points should always be considered as predisposing to suppurative tenosynovitis.

3. Time must not be lost in making a diagnosis, as every hour lost diminishes the patient's chance of a good end-result.

4. Wounds due to human bites should be primarily debrided.

5. The hemolytic streptococcus is the most frequent invading organism. The wound healing and end-results have varied considerably with the different micro-organisms.

6. Conservative treatment in gonococcus tenosynovitis, owing to the resemblance of this condition to tenosynovitis due to the pyogenic micro-organisms, is not without danger.

7. A tendon sheath already infected may be secondarily contaminated by another variety of micro-organism through careless technic. Such cases frequently have bad end-results.

8. Tendon sheath infections which are temporized with by means of inadequate and poorly placed incisions usually do badly.

9. Employment of special delicate instruments; careful dissection in a bloodless field, and the use of small strips of binding silk and rubber dam as drainage material, to be early removed, are recommended.

10. A revised technic described above, in which a painstaking effort is made to keep the wounds uncontaminated, has yielded 100 per cent. better results than our previous methods.

11. Early active motion, following almost immediately after recovery from the anaesthesia, is most advisable. Soaking in hot solutions will aid materially in attaining this objective, but a great deal depends on the cooperation of the patient.

12. It stands to reason that these patients should be hospitalized, as the foregoing treatment cannot be carefully supervised in ambulatory cases. They should be kept in the ward until their wounds are almost, if not quite, healed, as an important safeguard against secondary contamination.

13. The presence of, or a tendency to, chronic arthritis in the fingers makes a poor prognosis for the recovery of function.

14. In recapitulation, to attain optimum results in suppurative tenosynovitis the desiderata are: (*a*) early diagnosis and immediate operation; (*b*) properly placed, adequate incisions, draining all collections of pus; (*c*) avoidance of unnecessary trauma; (*d*) early removal of drains; (*e*) early and continued active motion, and (*f*) prevention of secondary contamination of the infected sheath.

CORRESPONDENCE

"BLOOD TRANSFUSION: A STUDY OF TWO HUNDRED AND FORTY-FIVE CASES"

To the Editor.—Dr. Horsley's report, under "Correspondence" in the September issue of the ARCHIVES, of thirty direct blood transfusions, in addition to the twenty-four transfusions he had previously reported as being performed without a subsequent chill or unusual rise of temperature, is a remarkable one. It speaks well for his and for his associates' technical ability in vascular surgery and justifies the particular method used by them. However, other writers have reported many cases of direct transfusions of blood by vascular suture and cannula followed by severe reactions; so that it can hardly be said in general to be a method "that is not followed by a varying percentage of reactions." There have been exceptional series of cases by other methods of transfusion. The late Dr. Lindeman reported 214 cases of blood transfusion by the syringe cannula technic without a subsequent chill; yet one would hardly claim that technic to be free from posttransfusion reactions. There have been a small number of consecutive cases of transfusion at Barnes Hospital without reaction. The word reaction is used to include all manifestations of agglutination, hemolysis, anaphylaxis, chills, febrile reactions, etc.

This series of fifty-four cases without a posttransfusion reaction is more interesting in view of the evidence lately presented by Guthrie and Huck in the *Bulletin of the Johns Hopkins Hospital,* "On the Existence of More Than Four Iso-Agglutinin Groups in Human Blood." I have thought that part of our posttransfusion reactions might be due to some of these heretofore unknown agglutinins, but evidently they are not great factors in reactions, as surely they would have caused a reaction in a few of the fifty-four cases reported. It will be interesting to know Dr. Horsley's method of determining compatibility of blood.

Transfusion of arterial instead of venous blood may be advantageous, but I cannot agree with Dr. Horsley that the "measurement of the amount of blood transfused seems immaterial." The knowledge of the quantity of blood transfused seems essential for the welfare of both donor and recipient, as well as the rate of flow of the blood, which is also unknown in a direct transfusion.

Dr. Horsley has suggested in his letter that there are technical difficulties in a direct transfusion, and he mentions the aversion of most professional donors to having their blood vessels exposed and incised. He also writes, in his book "Surgery of the Blood Vessels" of "some unsatisfactory results from a mechanical standpoint" in his early cases performed by this method. There is a current objection among professional donors in this locality to any operation on their vessels except puncture.

Furthermore, direct transfusion by vessel anastomosis seems to offer a greater opportunity than other methods for the formation of thrombi and emboli, for intravascular entrance of air and for clotting, to cause a failure of the transference of blood. Many transfusions are emergency procedures, and there is not time to make a blood Wassermann test on the recipient or to determine in certain recipients whether there is a septicemia present before

transfusion. The apposition of the tissue of such a recipient to a donor's open wound is not desirable and may be mentioned as an objection to the method.

These factors militate against ease of performance of a direct transfusion by vascular suture or cannula and, hence, against its becoming a popular general method. In spite of Dr. Horsley's outstanding record of no reactions following fifty-four transfusions and the fact that "posttransfusion reactions are harmful," I believe technics other than direct transfusion by vessel anastomosis are preferable because of the objections mentioned and that they will be rightfully used except by the few who possess the technical skill characteristic of Dr. Horsley's clinic, which is necessary for direct transfusion.

GLOVER H. COPHER, St. Louis.

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